Eriogonum visheri A. Nelson (Visher's buckwheat): A Technical Conservation Assessment

Prepared for the USDA Forest Service, Rocky Mountain Region, Species Conservation Project

December 18, 2006

Juanita A. R. Ladyman, Ph.D.
JnJ Associates LLC
6760 S. Kit Carson Cir E.
Centennial, CO 80122

Peer Review Administered by
Center for Plant Conservation

Ladyman, J.A.R. (2006, December 18). *Eriogonum visheri* A. Nelson (Visher's buckwheat): a technical conservation assessment. [Online]. USDA Forest Service, Rocky Mountain Region. Available: http://www.fs.fed.us/r2/projects/scp/assessments/eriogonumvisheri.pdf [date of access].

ACKNOWLEDGMENTS

The time spent and help given by all the people and institutions listed in the reference section are gratefully acknowledged. I would also like to thank the North Dakota Parks and Recreation Department, in particular Christine Dirk, and the South Dakota Natural Heritage Program, in particular David Ode, for their generosity in making their records, reports, and photographs available. I thank the Montana Natural Heritage Program, particularly Martin Miller, Mark Gabel of the Black Hills University Herbarium, Robert Tatina of the Dakota Wesleyan University, Christine Niezgoda of the Field Museum of Natural History, Carrie Kiel Academy of Natural Sciences, Dave Dyer of the University of Montana Herbarium, Caleb Morse of the R.L. McGregor Herbarium, Robert Kaul of the C. E. Bessey Herbarium, John La Duke of the University of North Dakota Herbarium, Joe Washington of the Dakota National Grasslands, and Doug Sargent of the Buffalo Gap National Grasslands - Region 2, for the information they provided. I also appreciate the access to files and assistance given to me by Andrew Kratz, Region 2 USDA Forest Service, and Chuck Davis, U.S. Fish and Wildlife Service in Denver. The information provided by Prof. James Reveal was very valuable, and I appreciate the time he spent answering my questions. In addition, I would like to thank Deb Golanty at the Helen Fowler Library, Denver Botanic Gardens, for her persistence in retrieving some rather obscure articles. I also would like to acknowledge the generosity of D.L. Gustafson and Martin Wefald, of Montana State University, for making their Graphical Locator available on the Internet. I appreciate the reviews of Kathy Carsey, Prof. Richard Spellenberg, and an anonymous reviewer and thank them for their time and consideration of the assessment.

AUTHOR'S BIOGRAPHY

Juanita A. R. Ladyman received her B.Sc. degree (with First-class honors) in Biochemistry from London University, England. Her first professional position was as plant pathology laboratory technician and, later, as Greenhouse research supervisor with the Arid Lands Research Center on Sadiyat Island in the United Arab Emirates. She obtained her Ph.D. degree in Botany and Plant Pathology from Michigan State University where she was also a research assistant with the D.O.E. Plant Research Laboratory. She worked as a plant physiological ecologist and plant scientist for Shell Development Company conducting research on the physiology, ecology, and reproductive biology of economically important plant species and their wild relatives. She then worked for a plant biotechnology company in their Genetic Transformation and Plant Tissue Culture Division. For the last 15 years she has worked in the area of conservation, particularly on rare, endemic, and sensitive plant species in the southwest United States. For three years of that time, she was the botanist with the New Mexico Natural Heritage Program. She has conducted research and monitoring programs on both non-vascular and vascular species. She currently is a partner in JnJ Associates LLC, an environmental consulting company in Colorado.

COVER PHOTO CREDIT

Eriogonum visheri (Visher's buckwheat). Cover photograph courtesy of David Ode, South Dakota Game, Fish, and Parks Department, used with permission.

LIST OF ERRATA

Summary of Key Components for Conservation of *Eriogonum visheri*

Status

Eriogonum visheri (Visher's buckwheat) is a small, inconspicuous summer annual plant endemic to the badlands of North Dakota, South Dakota, and Montana. . The Northern Region (Region 1) and the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS) have designated *E. visheri* a sensitive species. The taxon is also on the watch list of the Bureau of Land Management in Montana. *Eriogonum visheri* was designated a Category 2 candidate for listing as endangered or threatened under the federal Endangered Species Act (16 U.S.C. 1531 et seq.). It lost that status in 1996 when the U.S. Fish and Wildlife Service (USFWS) eliminated the Category 2 designation, but it still remains a species of management concern for the USFWS. NatureServe assigns *E. visheri* the global rank of vulnerable (G3). The species is designated critically imperiled (S1) by the Montana Natural Heritage Program, between imperiled and vulnerable (S2S3) by the North Dakota Natural Heritage Inventory, and vulnerable (S3) by the South Dakota Natural Heritage Program. These state and global ranks indicate the rarity and vulnerability of a taxon, but they have no regulatory weight.

Primary Threats

Eriogonum visheri is vulnerable to habitat loss and degradation because it is restricted to a limited suite of edaphic conditions derived from geological formations within a limited geographic range. Much of the range of *E. visheri* is within the Williston Basin of western North Dakota, eastern Montana, and northwestern South Dakota. This basin is rich in extractable minerals and oil and gas, and so it has been and continues to be affected by activities associated with resource extraction. While future levels of resource extraction activity are likely to be substantial in many parts of the taxon's range, they are not likely to impact *E. visheri* occurrences in the Buffalo Gap National Grassland of Region 2 because of a dearth of oil, natural gas, or locatable minerals there.

All activities that lead to significant soil disturbance (e.g., mechanized vehicle traffic, livestock grazing) are likely to present a significant threat to the long-term persistence of *Eriogonum visheri* occurrences. While disturbance may open areas to initial colonization by *E. visheri*, it also increases the probability of colonization by invasive non-native plants. *Eriogonum visheri* evolved in habitats where interspecies competitive pressures are very low, and evidence suggests that infestations of aggressive plant species are a significant threat to sustainable populations of this species over the long term. Disturbance can also reduce or eliminate the seed bank, which appears to be the primary long-term survival strategy of the species. *Eriogonum visheri* is likely to be palatable to non-selective herbivores, such as livestock, some species of wildlife, and arthropods, but the potential magnitude of the effect of browsing is not known.

Primary Conservation Elements, Management Implications, and Considerations

Eriogonum visheri is an annual, edaphic endemic restricted to the badlands of western South Dakota, southwestern North Dakota, and eastern Montana. Over the last century, approximately 119 occurrences have been reported, and 22 of these are on Region 2 National Forest System land. *Eriogonum visheri* occurrence sizes are highly variable both spatially and temporally. Because occurrences undergo local extirpations and other areas may experience only temporary colonization, it is difficult to evaluate trends in abundance and occurrence extent without systematic monitoring. Estimating changes in range and abundance that might have occurred prior to 1980 is not possible because of a lack of information.

The seed bank appears to be very important in maintaining populations of *Eriogonum visheri* over the long term. However, this facet of its life history and biology makes *E. visheri* vulnerable to disturbance. Occupied habitat is very difficult to determine for a species where a large proportion of its population may reside in the seed bank. Biological evaluations that concentrate on areas occupied by aboveground plant stems may miss areas occupied by dormant seeds. This situation is not unique to *E. visheri* and poses a problem in achieving adequate habitat conservation for any plant species with similar life history characteristics.

Relatively little is known about this taxon's biology or ecological requirements. Its precise habitat requirements, the role of disturbance in its life history, and seed dispersal mechanisms of *Eriogonum visheri* are not known. Colonies are widely distributed and typically occupy less than 1 percent of the ostensibly suitable ("potential") habitat that is surveyed.

The role of disturbance in the species' life history is unknown. *Eriogonum visheri* is adapted to soils that crack and swell and experience erosion from precipitation and wind. Apparently the seeds are primarily dispersed by surface run-off; plants tend to grow in microdrainages and places where water would accumulate, even if only fleetingly, during a storm.

Maintaining *Eriogonum visheri* as a USFS sensitive species in Region 2 ensures that it is considered during management planning. Sensitive species status encourages periodic evaluation of its condition on National Forest System land. Three occurrences on the Buffalo Gap National Grassland (Region 2) exist within an area that is open only to non-motorized recreation. This area's management prescription affords the species some protection from disturbance. It would be desirable to have additional areas where occurrences would be assured of protection from anthropogenic activities because this taxon's restrictive habitat requirements make it particularly vulnerable to the consequences of habitat degradation. Establishing additional formal protective areas on the Buffalo Gap National Grassland would have particularly high conservation value in maintaining genetic diversity of the species since several sites that are relatively far apart and apparently support large, vigorous occurrences could be protected.

TABLE OF CONTENTS

EDITORS: Kathy Carsey and Janet Coles, USDA Forest Service, Rocky Mountain Region

List of Tables and Figures

Tables:

Figures:

INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Eriogonum visheri* is the focus of an assessment because it is designated a sensitive species in Region 2 (USDA Forest Service 2003a, 2005). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (Forest Service Manual 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses what is known of the biology and ecology of *Eriogonum visheri* throughout its range in North America and Region 2. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production. The lack of information on *E. visheri* leads to some constraints on the specificity of information for particular locales. Furthermore, completing the assessment promptly required establishment of limits on making further analysis of existing, but unanalyzed, field data. For example, the relationship between regional climate and *E. visheri* abundance might be evaluated using the raw data available in field notes, but this type of analysis was beyond the scope of this report.

Goal

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, and conservation status of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Rather, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications).

Scope

This assessment examines the biology, ecology, and management of *Eriogonum visheri* with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region. Although some of the literature relevant to the species may originate from field investigations outside the region, this document places that literature in the ecological and social contexts of Region 2. This assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *E. visheri* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis, but placed in a current context.

In producing the assessment, peer-reviewed (refereed) literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. The assessment emphasizes the refereed literature because this is the accepted standard in science. Some non-refereed literature was used in the assessment when information was otherwise unavailable. In some cases, non-refereed publications and reports may be regarded with greater skepticism. However, many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations of phenology or reproductive biology. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have prevented work in subsequent years. One year of data is generally considered inadequate for publication in a refereed journal but still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (for example, Natural Heritage Program and herbarium records) were important in estimating the geographic distribution and population sizes of *Eriogonum visheri*. These data required special attention because of the diversity of persons and methods used in collection. Records that are associated with locations at which herbarium specimens were collected at some time were considered the most reliable.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas are measured against observations. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, strong inference as described by Platt, suggests that experiments will produce clean results (Hillborn and Mangel 1997), which is not always the case in the ecological sciences. The geologist, T.C. Chamberlain (1897) suggested an alternative approach to science where multiple competing hypotheses are confronted with observation and data. Sorting among alternatives may be accomplished using a variety of scientific tools, including experimentation, logical inference, and modeling. These are often the tools of ecological science because it is frequently difficult to conduct critical experiments. Therefore, there is a substantial reliance on observation, inference, good thinking, and models to guide understanding of ecological processes (Hillborn and Mangel 1997). Consequently, in this assessment, the strength of evidence for hypotheses is noted and alternative explanations are described when appropriate.

One element of uncertainty regarding *Eriogonum visheri* lies in accurately determining population size trends for this small, inconspicuous, annual plant. Range-wide, there currently appears to be tens or even hundreds of thousands of *E. visheri* individuals, but occurrence sizes are temporally and spatially highly variable. Annual monitoring over many years is needed to determine an accurate population trend. Another uncertainty results from population size estimates derived from observations made at a distance from the plants. Individuals can remain standing for at least two years after dying, which leads to the potential for over-estimating the number of individuals that are reproducing in any one year. A further uncertainty lies in evaluating the extent to which the taxon is vulnerable to stochasticities. *Eriogonum visheri* typically occupies less than 1 percent of apparently suitable habitat, and because colonies may exist as dense patches, local impacts could substantially affect the total population.

Publication of Assessment on the World Wide Web

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web (http//:www.fs.fed.us/r2/projects/scp/assessments/index.shtml). Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, Web publication facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project were peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

Management Status and Natural History

Management Status

Both Region 1 and Region 2 of the USFS have designated *Eriogonum visheri* a sensitive species (USDA Forest Service 2003a, USDA Forest Service 2005, Washington personal communication 2005). A USFS sensitive species is a plant or animal “species identified by a Regional Forester for which population viability is a concern, as evidenced by a significant current or predicted downward trend in population numbers or density [and/or] a significant current or predicted downward trends in habitat capability that would reduce a species’ existing distribution” (Forest Service Manual 2670.5 Definitions 19, Bosch 2004).

Eriogonum visheri is on the watch list for the Bureau of Land Management (BLM) in Montana (Montana Natural Heritage Program 1997-2005). A species on a BLM watch list is one that is either known to be imperiled and suspected to occur on BLM lands; suspected to be imperiled and documented on BLM lands; or needing further study for other reasons (U.S. Bureau of Land Management 6840 Manual in Montana Natural Heritage Program 1997-2005).

Eriogonum visheri was designated a Category 2 candidate for listing as endangered or threatened under the Endangered Species Act (16 U.S.C. 1531 et seq.). Category 2 included taxa for which “proposing to list as threatened or endangered is possibly appropriate, but for which sufficient data on biological vulnerability and threats are not currently available to support proposed rules” (U.S. Fish and Wildlife Service 1993). Region 6 of the U.S. Fish and Wildlife Service (USFWS) was the lead authority (U.S. Fish and Wildlife Service 1993). In 1993, the USFWS added abundance trend evaluations for each species to assist in making listing decisions but reported that the trend of *E. visheri* was unknown. In 1996, the USFWS discontinued designating species beyond primary Candidates for listing or those that are actually listed as Threatened or Endangered. Therefore as of February 28 1996, *E. visheri* was no longer listed as a Candidate species, but it remained a species of management concern (U.S. Fish and Wildlife Service 1995).

The USFWS relies on several sources of information to identify those species that may be vulnerable and warrant protection. These sources include NatureServe's database system (NatureServe 2005), state conservation and natural resource program databases, and lists of species that state government agencies designate as rare, endemic, or endangered. In their strategic plan of action for the Upper Missouri-Yellowstone-Upper Columbia River (MOYOCO) ecosystem, the USFWS listed *Eriogonum visheri* as a "plant species of Special Concern" (U.S. Fish and Wildlife Service 2000). In 1996, this species was included on the IUCN Red List of rare plants (Sidle 1998), but it has since been dropped (IUCN 2004). The reason for its exclusion was not documented.

NatureServe and state natural resource conservation programs rank sensitive taxa at state (S) and global (G) levels on a scale of 1 to 5. A rank of 1 indicates the most vulnerable and 5 the most secure (see Ranks in the **Definitions** section). NatureServe assigns *Eriogonum visheri* the global rank[1] of vulnerable (G3). It is designated critically imperiled (S1) by the Montana Natural Heritage Program (1997-2005), imperiled to vulnerable (S2S3) by the North Dakota Natural Heritage Inventory (2005), and vulnerable (S3) by the South Dakota Natural Heritage Program (2005). These ranks have no regulatory status.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

There are approximately 119 known occurrences of *Eriogonum visheri*. Of these, approximately 53 occur on National Forest System lands (44 percent), two are within the Badlands National Park, approximately eight are on land managed by state agencies, and one is on BLM land (**Table 1**, **Table 2**). The remaining occurrences were reported from Native American tribal lands and private landowners. Several occurrences encompass multiple land management authorities.

Of the approximately 53 occurrences on National Forest System lands, about 31 *Eriogonum visheri* occurrences are on the Dakota Prairie Grasslands and the Custer National Forest managed by Region 1. The Dakota Prairie Grasslands was established as a unit of the USDA Forest Service in 1998. The Dakota Prairie Grasslands Supervisor's Office, located in Bismarck, North Dakota, manages the Little Missouri National Grassland, the Sheyenne National Grassland, the Cedar River National Grassland, and the Grand River National Grassland. Twenty-five *E. visheri* occurrences have been reported from the Little Missouri National Grassland and approximately five occurrences from the Grand River National Grassland. No occurrences have been reported from the other two national grasslands. However, apparently suitable habitat for *E. visheri* is available on the Cedar River National Grassland, and the plant may occur there. Approximately 22 *E. visheri* occurrences are on the Buffalo Gap National Grassland that is part of the Nebraska National Forest and managed by Region 2.

National Forest System lands

Federal codes and regulations pertaining to federal actions or to those on USFS lands include the National Environmental Policy Act of 1969 (42 U.S.C. 4321-4347), the Organic Administration Act of 1897 (16 U.S.C. 475), the Multiple Use – Sustained Yield Act of 1960 (16 U.S.C. 528), the National Forest Management Act of 1976 (16 U.S.C. 1600-1602, 1604, 1606, 1608-1614), the Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701-1782, FSM 2729), the Forest Service Manual, and individual Forest Management Plans. Region 1 and Region 2 both designate *Eriogonum visheri* a sensitive species. USFS sensitive species objectives are to:

- ❖ develop and implement management practices to ensure that species do not become threatened or endangered because of USFS actions

- ❖ maintain viable populations of all native and desired nonnative wildlife, fish, and plant species in habitats distributed throughout their geographic range on National Forest System lands; develop and implement management objectives for populations and/or habitat of sensitive species (Forest Service Manual 2670.22 Sensitive Species, Bosch 2004).

[1]For definitions of G and S ranks see **Definitions** section at the end of this document.

Table 1. Occurrences of *Eriogonum visheri* in South Dakota.

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
1	a	Meade	Privately owned rangeland	22-Aug-1986	Johnny Creek badlands, 3 miles north and 2 miles east of Howes Corner; pasture trail leads east from Highway 73; occurrence extends across four sections	Plants on mostly barren slopes and outwash of Hell Creek formation	More than 1,000 plants occurring as localized colonies; badlands are located north of trail	*D.J. Ode #86-68* SDC in Ode (1987); SDNHP4
2	a	Meade	Private land	17-Jul-1971 16-Aug-1983 22-Aug-1986	1971: 24.5 miles south of Faith 1983: Highway 73, approximately 3.8 miles north of Howes Corner	1971: Base of eroded butte, gravel, clay soil 1983: Occurring with species of *Schedonnardus*, *Distichlis*, *Grindelia*, and *Gutierrezia* in 70 to 80 percent bare clay soil; with *Atriplex* spp. and *Astragalus racemosus*	1971: Abundant 1986: Several dozen plants; two discrete patches of plants separated by a road	*S. Stephens #49519* 1971 MARY, KANU; *D.J. Ode #83-186* 1983 MARY, SDC; Observation in 1986 in Ode (1987) and SDNHP
3	N/A	Meade	Privately owned rangeland	23-Aug-1986	Little Turtle Creek badlands. 17 miles south and 1 mile east of Faith; trail leading east from Highway 73; occurrence across two sections	Hell Creek formation badlands on mostly barren shale and clay slopes and outwash	Several thousand plants occurring as localized colonies	*D.J. Ode #86-69* SDC in Ode (1987); SDNHP
4	N/A	Meade	Privately owned rangeland	17-Jul-1971 16-Aug-1983	1971: 6.5 miles south of Faith 1983: Scaffold Creek Drainage, 6.8 miles south of Faith	1971: Base of eroded butte, gravel, clay soil 1983: An erosional patchwork of barren clay substrate and short grass prairie; plants along footslope of short erosional ridge and in road ditch; occurring with *Gutierrezia*, *Atriplex argentea*, and *Artemisia cana* on barren clay	1971: Abundant 1983: Thinly scattered	*S. Stephens #49522* 1971 KANU; *D.J. Ode #83-187* 1983 SDU in Ode (1987); SDNHP
5	N/A	Meade	Privately owned rangeland	24-Aug-1986	Signal Butte Badlands, 18 miles west and 1 mile north of Faith; occurrence across two sections	Plants on dense clay slopes and gumbo sand outwash of Hell Creek formation	Several hundred plants observed distributed over localized colonies "Extensive habitat extends north and west of site" (Ode 1987)	*D.J. Ode #86-74* NEB in Ode (1987); SDNHP
6	N/A	Meade	Privately owned rangeland	23-Aug-1986	Beaver Dam Creek, 8 miles east and 4.1 miles south of Maurine; occurrence over two sections	Eroded bluffs of intermittent drainage; plants on barren clay soil of road cut and adjacent eroded stream bluffs	Several dozen plants in few localized colonies	*D.J. Ode #86-72* BHSC in Ode (1987); SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
7	N/A	Meade	South Dakota Dept. of School and Public Lands, private land	23-Aug-1986	Lemmon Butte, 11 miles east and 4 miles north of Opal; occurrence across two sections	Eroded butte just east of ranch buildings; plants on barren shale and clay slopes and outwash	Several thousand plants occurring as localized colonies scattered east and west of butte	*D.J. Ode #86-71* SDC, SDU in Ode (1987); SDNHP
8	N/A	Meade	Private land	10-Aug-1912 17-Jul-1971 16-Aug-1983 23-Aug-1986	1912: Faith 1971: 1 mile west of Faith 1983: Spook Creek headwaters, 1.1 miles west of Faith	1912: Alkali Flats 1971: Base of eroded butte, gravel, clay soil 1983: Shallow badlands topography with patches of vegetation; surface strewn with limonite cobbles; plants on mostly barren slopes and outwash of Hell Creek formation	1971: Abundant 1986: 1,000 plants occurring as localized colonies	*L.R. Moyer #235* 1912 MN in Ode (1987); *S. Stephens #49523* 1971 KANU; *D.J. Ode #86-188* 1983 SDC, observation in 1986 in Ode (1987); SDNHP
9	N/A	Ziebach	Privately owned rangeland	24-Aug-1986	Butcher Creek headwaters, 4 miles east and 0.5 miles south of Faith	Scattered patches of barren outcrop in eroded grassland. Hell Creek formation; plants along eroded ridges and outwash	Several dozen plants on small area of exposed substrate	*D.J. Ode #86-73* SDC in Ode (1987); SDNHP
10	N/A	Perkins	Privately owned rangeland	31-Aug-1986	Cedar canyon, 6.5 miles west and 5.5 miles north of Maurine	Huge canyon in Hell Creek formation of mostly barren rock exposures; plants on convex ridges, saddles, shelves and benches near top of relief in gray-black clay	"Undoubtedly several hundred thousand plants scattered as localized colonies"	*D.J. Ode #86-100* SDC, SDU in Ode (1987); SDNHP
11	N/A	Perkins	Privately owned rangeland	17-Jul-1971 16-Aug-1983	1971: 4.5 miles south of Usta 1983: Highway 73 mile-marker 187, 4.8 miles south of Usta, 10 miles north of Highway 212 on shallow west northwest, just east of highway	1971: Eroded prairie hillsides; rocky clay soil 1983: Plants scattered along micro-drainage on bare clay substrate of Hell Creek formation	1971: Abundant 1983: Approximately 50 plants observed scattered along micro-drainage; in same area report of plants being "abundant in rocky clay in eroded prairie"	*S. Stephens #49526* 1971 MARY, KANU; *D.J. Ode #83-189* MARY 1983; Ode (1987); SDNHP
12	N/A	Perkins	Privately owned rangeland	31-Aug-1986	Arrowhead Butte, 9 miles north of Faith	Hell Creek formation butte with extensive badlands to the west; on cobble-covered clay mounds and outwash	Several hundred plants observed; "Potentially many thousand plants."	*D.J. Ode #86-97* SDU in Ode (1987); SDNHP
13	N/A	Perkins	Privately owned rangeland	24-Aug-1986	Starve Out Creek badlands, 16 miles north of Maurine	Erosional exposures of Hell Creek formation along cutbanks of stream channel	Few (several) hundred plants observed in three colonies; "Extensive habitat downstream needs to be surveyed."	*D.J. Ode #86-75* BHSC in Ode (1987) SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
14	N/A	Perkins	Privately owned rangeland	31-Aug-1986	Englewood township badlands, 2 miles north of Usta, east and west of Highway 73; Hell Creek formation, butte east of highway and eroded badlands west of highway	Plants on mostly barren slopes of butte	Several dozen plants observed; "Area west of highway needs to be surveyed."	*D.J. Ode #86-98* SDC in Ode (1987); SDNHP
15	N/A	Perkins	Privately owned rangeland	31-Aug-1986	Moreau River bluffs, 1.5 miles west of Usta, north of road	Small shale outcrops on low hillside bluff; likely Hell Creek formation	Several hundred plants in few localized colonies; plants on east bluff but absent on west bluff; identical adjacent habitat has no *E. visheri* but supports dense colonies of *Salsola iberica*	*D.J. Ode #86-99* SDU in Ode (1987); SDNHP
16	N/A	Ziebach	Cheyenne River Indian tribal lands	19-Aug-1984	Thunder Butte Road, badlands 9.3 miles south of Highway 20 junction; occurrence across two sections	Plants on mostly barren shale slopes of the Hell Creek formation	Several dozen plants; "Managed as rangeland."	*D.J. Ode #84-150* 1984 SDC, SDU in Ode (1987); SDNHP
17	N/A	Perkins	Privately owned rangeland	18-Aug-1984	Rabbit Butte, 25 miles north of Maurine	In badland breaks just north of butte and on barren knobs and ground around base of butte; plants on barren substrates of Hell Creek formation; associated with *Agropyron smithii*, *Poa sandbergii*, species of *Gutierrezia*, *Distichlis*, *Kochia*, and *Chrysothamnus*	Locally common; dead plants abundant, live plants few	*D.J. Ode #84-147* 1984 KANU, MARY, RM, SDC, SDU; SDNHP
18	N/A	Ziebach	Privately owned rangeland with mineral rights owned by the Cheyenne River Sioux Tribe	27-Aug-1986	Thunder Butte badlands, 4 miles west and 4 miles south and west of Glad Valley; approximately 2 miles north of Thunder Butte	Eroded Hell Creek formation at upper end of drainage; plants on mostly barren, cobble covered clay mounds and slopes along eroded stream-bed	Several hundred plants in localized colonies	*D.J. Ode #86-80* SDU in Ode (1987); SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
19	N/A	Ziebach	Cheyenne River Indian tribal lands, private land	27-Aug-1986	Irish Creek headwaters, 7.5 miles west of Isabel. Irish Creek headwaters, 9.5 miles east of Glad Valley	Isolated Hell Creek formation, 'Hay stack' butte; plants on mostly barren shale slopes and benches	Few dozen plants (estimate up to approximately 200) in three localized colonies; several dozen plants as scattered colonies on barren clay slopes of badlands butte just south of highway; specimen at Dakota Wesleyan University is one plant in flower and fruit; land managed as rangeland (Ode 1987)	*D.J. Ode #86-78* 1986 DWU, Ode (1987); SDNHP
20	N/A	Harding	USDA Forest Service (USFS) Region 1 Custer National Forest	08-Jul-1994	Slim Buttes; 1mile west of Highway 79, 0.5 miles north of Custer National Forest boundary	Plants on a clayey silt outcrop and a sandy silt outwash with limonite cobbles, *Distichlis* sp., *Eriogonum pauciflorum*, *Atriplex dioica*, and *Iva axillaris*	Approximately 1,000 plants	SDNHP
21	N/A	Ziebach	Cheyenne River Indian tribal lands, private land	19-Aug-1984	Beaver Trap Creek badlands; Thunder Butte Road, 1 mile south of Highway 20	Plants on barren badland slopes and footslopes (outwash). Hell Creek formation. Associated with *Helianthus petiolaris*, *Artemisia cana*, *A. campestris*, species of *Gutierrezia*, *Kochia*, and *Grindelia*	Locally abundant, several hundred plants	*Ode #84-148* 1984 KANU, SDC, SDU in Ode (1987); SDNHP
22	N/A	Ziebach	Cheyenne River Indian tribal lands	Jun-1924 1986	13 miles west of Isabel. (no plants observed in 1986)	No information	No colonies were located at this site although potential habitat is present (Ode 1987)	*J.W. Moore #726* 1924 MN; SDNHP
23	N/A	Perkins	Likely private land	03-Aug-1912 1986	1912: Meadow, approximately 12 miles east of Bison 1983: Not found within a 2 mile radius of Meadow (the area is mostly cropland)	No information	1912: No details; Holotype specimen 1986: "No colonies were located at this site although potential habitat is present" (Ode 1987). "No populations or suitable habitats were located within a 2-mile radius of the present town of Meadow. The area is now predominately cropland. The present town site of Meadow was established in 1907 but originally was a stage station located on Big Meadow Flat, some 10 miles southeast of the present town site" (Sneve 1973 in Ode 1987).	*S.S. Visher #536* 1912 RM; Ode (1987); SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
24	N/A	Corson	Standing Rock Indian Reservation tribal trust land, private land	29-Aug-1986	Cedar Township badlands, 9.8 miles south and 6.5 miles west of Highway 65 Grand River Bridge; occurrence across four sections	Scattered outcrops of Hell Creek formation badlands. On barren shale mounds, slopes, and ridges	Several thousand plants occurring as localized colonies; managed as rangeland	*D.J. Ode #86-93* 1986 BHSC in Ode (1987); SDNHP
25	b	Corson	Privately owned rangeland	29-Aug-1986	Cottonwood Creek badlands; 8.8 miles south and 2.5 miles west of Highway 65 Grand River Bridge	Hell Creek badlands at upper end of drainage. Plants on mostly barren slopes, mounds and outwash. On barren clay slopes, mounds and outwash of Hell Creek formation badlands	Dense scattered colonies; more than 100,000 plants as dense colonies; seed collected from this site was sent to the Center of Plant Conservation	*D.J. Ode #86-90* 1986 BHSC (SDU, SDC in Ode 1987); SDNHP
26	b	Corson	Privately owned rangeland	29-Aug-1986	Abandoned Keller Mine, 8.8 miles south and 3 miles west southwest of Highway 65 Grand River Bridge	Large, barren spoil bank of Hell Creek formation overburden. Plants in crevices or outwash near east end of mound.	Few, scattered plants in five clusters	*D.J. Ode #86-92* 1986 SDC in Ode (1987); SDNHP
27	b	Pennington	Badlands National Park	15-Jul-1940	Wall, Bad Lands, South Dakota	Badlands. "Located in gulley."	No information	*D. Berkheimer #2063* PH
28	c	Pennington	USFS Region 2 Buffalo Gap National Grassland	23-Jul-1996	Steer pasture allotment approximately 5 miles southeast of Wall	Site 1 is located on south-facing midslope along badlands wall, Site 2 along base of badlands wall, Site 3 along base of badlands wall away from site 2	Approximately a total of 10,000 plants distributed in four sites; plants observed in 1993: Site 1: 3,200; Site 2: 6,000; Site 3: 300; Site 4: 160. Plants observed in 1996: Site 1, 3,800; Site 2: 7,000; Site 3: 400; Site 4: 4,400	SDNHP
29	c	Pennington	USFS Region 2 Buffalo Gap National Grassland	23-Jul-1996 23-Jun-2005	Bloom Basin, Steer pasture allotment approximately 6 miles south-southeast of Wall	1996: Site 5 is along top and base of erosional terrace. Site 6 is mostly barren, nearly level alluvium 2005: In typical badlands habitat; soils are deep heavy clay	1996: Site 5: 2,000-2,500 plants. 1996: Site 6: 2,000-2,800 plants. 2005: 20 - 50 plants	1996 report from SDNHP; 2005 from Kostel (2006)
30	N/A	Perkins	USFS Region 1 Grand River National Grassland, private land	30-Aug-1986	L.J. Seim allotment, approximately 7 miles south and 3.5 miles west of Highway 73 Grand River Bridge	Barren shale mound and outwash along cutbank of drainage on Hell Creek formation	Several hundred plants observed as localized colonies. Managed for rangeland	*D.J. Ode #86-95* NEB in Ode (1987); SDNHP
31	N/A	Perkins	USFS Region 1 Grand River National Grassland	28-Aug-1986	Pasture 9-East Unit, 4 miles south and 6 miles east of the Highway 73 Grand River Bridge	Scattered Hell Creek badlands interspersed in mixed grass prairie. Plants on mostly barren shale slopes and outwash	Several thousand plants in widely scattered localized colonies	*D.J. Ode #83-192* SDC in Ode (1987); SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
32	N/A	Perkins	Privately owned rangeland	17-Aug-1983 30-Aug-1986	Southeast Huggins Township (TWSP); Badlands, 7 miles south of Grand River on Highway 73 then 3.5 miles east; occurrence extends over four sections	Hell Creek formation badlands mounds, clay flats and scattered patches of grassland vegetation on side of gravel road. Plants on slopes and outwash with *Distichlis* sp., *Artemisia frigida*, *Gutierrezia* sp., and *Atriplex argentea*	Several thousand plants in widely scattered localized colonies	*D.J. Ode #83-193* 1983 SDC in Ode (1987); 1986 in Ode (1987) and SDNHP
33	d	Corson	Standing Rock Indian tribal land	17-Aug-1983	Somber Butte, 6.2 miles north of Athboy; approximately 2.5 miles northwest of Black Horse Butte	Restricted to "somber beds" of Hell Creek formation above contact with sandy bed of Colgate member of Fox Hills formation. On shale-clay shelves and slopes among limonite rocks and cobbles. Occurring with *Gutierrezia sarothrae* and *Machaeranthera canescens*	Fairly abundant. Managed for rangeland	*D.J. Ode #83-195* MARY; SDNHP
34	d	Corson	Standing Rock Indian tribal land, private land	30-Aug-1986	Riverside Township Badlands, 4-1/2 miles northeast of Black Horse Butte; Riverside Township badlands, 3 miles east and 7.2 miles north of Athboy; long badland escarpment just south of Grand River	Plants occurring on mostly barren slopes and benches of the Hell Creek formation. On barren clayey slopes and benches just below summit of long, eroded ridge. Associated with species of *Atriplex*, *Artemisia*, *Chrysothamnus*, and *Gutierrezia*	Several dozen plants. Occasional as scattered colonies	*D.J. Ode #86-96* DWU; Ode (1987); SDNHP
35	N/A	Perkins	USFS Region 1 Grand River National Grassland	28-Aug-1986	Pasture 9-South unit, 4 miles south and 1.5 miles east of Highway 73 Grand River Bridge; occurrence over two sections	Scattered badland outcrops of Hell Creek formation within mixed grass prairie	Uncertain abundance. In Ode (1987): "Several dozen plants." In South Dakota Natural Heritage Program (2005): "More than 10,000 plants observed as localized colonies on mostly barren slopes and outwash." Managed for rangeland	*D.J. Ode #83-85* BHSC in Ode (1987); SDNHP
36	N/A	Perkins	State of South Dakota Division of Parks & Recreation, Private land	17-Aug-1983 30-Aug-1986	Shadehill Recreation Area Badlands 1983: 1.3 miles south and 1.5 miles west of Summerville 1986: 12.5 miles south and 1.5 miles west of Lemmon. [Area approximately 12 miles north of Meadow]	1983: Plants along base of east facing gumbo clay slope with species of *Distichlis*, *Machaeranthera*, *Gutierrezia*, and *Chrysothamnus* 1986: On barren Hell Creek formation slopes, mounds, and outwash. One site on east-facing gumbo clay slope on west side of pond	1983: Infrequent to locally abundant 1986: Several hundred plants observed in two areas 1986: "A large area has been searched but only 3 localities" were located. All area managed as rangeland (Ode 1987)	*D.J. Ode #83-192* 1983 MARY, SDC; *D.J. Ode #83-190* 1983 SDU, 1986 in Ode (1987); SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
37	N/A	Perkins	State of South Dakota Division of Parks & Recreation, private land [inholding on USFS Region 1 Grand River National Grassland]	17-Jul-1971	2 miles east and 17.5 miles north of Meadow in northeast Perkins County; just east of Shadehill Reservoir off Highway 73; occurrence extends over three sections	Base of eroded prairie hillside. Plants in dry gravelly clay soil	Abundant. Several colonies [number not reported]. Several precisely located colonies are known in this general vicinity	*H.A. Stephens #49529* KANU; SDNHP
38	N/A	Perkins	USFS Region 1 Grand River National Grassland and onto Shadehill Recreation Area Badlands	11-Jun-2001	5 miles south of Sommerville and road to Shadehill Reservoir on west side of Highway 73	In open area at base of eroded area with *Ceratoides lanata* and *Agropyron cristatum*	No information. Two specimens on sheet: one vegetative the other in flower	*R. Tatina #3077* DWU
39	N/A	Corson	Privately owned rangeland	29-Aug-1986	North Hump Creek Badlands, 3 miles west and 9 miles south of McIntosh	On small, cobble strewn, clay shelf above precipitous cliff	Few dozen plants on small shelf. Exposures of the Hell Creek formation are extensive along this ridge but no other colonies were found	*D.J. Ode #83-88* SDC in Ode (1987); SDNHP
40	N/A	Corson	Standing Rock Indian tribal land and Private land	29-Aug-1986	South Hump Creek Badlands, 12 miles west and 2.5 miles west of McIntosh; occurrence across two sections	Long eroded escarpment of Hell Creek formation. Plants on shale substrate near top of ridge	Less than 500 plants in two colonies. Cropland on south side of road. Most of area managed as rangeland. Despite extensive exposures of the Hell Creek formation are extensive along this ridge but no other colonies were found	*D.J. Ode #83-89* SDC in Ode (1987); SDNHP
41	N/A	Corson	Privately owned rangeland	19-Sep-1986	Whiteshirt Creek South, along Highway 65, 8.8 miles south of Highway 12 junction	Localized outcrops of Hell Creek formation. Plants on low cobble-strewn mound	Less than 500 plants in localized colonies (Ode 1987). Several dozen plants (SDNHP 2005). Grazing impact observed on 4 plants. *Salsola* invasion	*D.J. Ode #83-105* SDC in Ode (1987); SDNHP
42	N/A	Perkins	USFS Region 1 Grand River National Grassland	28-Aug-1986	Pasture 9 - North unit, side of Highway 73, 2.5 miles south of Grand River Bridge; occurrence extends over four sections	Scattered badland outcrops of Hell Creek formation and mixed grass prairie. Plants on mostly barren slopes and outwash	>10,000 plants observed as localized colonies.	*D.J. Ode #83-84* SDU: *D.J. Ode #83-86* SDC in Ode (1987); SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
43	N/A	Corson	Standing Rock Indian tribal land, private land	19-Sep-1986	White Shirt Creek North, along Highway 65, 3.5 to 6 miles south of Highway 12 Junction; occurrence across two sections	Hell Creek badland outcrops. Plants on mostly barren limonite cobble covered mounds and convex slopes	Several thousand plants occurring as localized colonies. Managed for rangeland	*D.J. Ode #83-104* NEB in Ode (1987); SDNHP
44	e	Pennington	USFS Region 2 Buffalo Gap National Grassland	23-Jul-1996	Steer pasture allotment approximately 9 miles south-southeast of Wall	Located along base and outwash of Brule/Chadron formation badlands mound just southeast of stock dam	Approximately 500 plants observed in 4 colonies.	SDNHP
45	e	Pennington	USFS Region 2 Buffalo Gap National Grassland	23-Jul-1996	Steer pasture allotment approximately 8 miles south-southeast of Wall; in Bloom Basin	Along base of Brule/Chadron badlands outcrop	Approximately 500 plants observed in 3 colonies.	SDNHP
46	N/A	Pennington	USFS Region 2 Buffalo Gap National Grassland	26-Jul-1996	North Whitewater Allotment, approximately 8 miles northwest of Cactus Flats	Plants located on upper and lower slope of Orella terrace, erosional outcrop between branches of Whitewater Creek	1991: Approximately 300 plants observed 1993: 314 (counted) in 164 square m (Schmoller 1993)	SDNHP
47	N/A	Pennington	USFS Region 2 Buffalo Gap National Grassland	24-Jul-1996	Conata West Allotment, approximately 2.5 miles north-northwest of Conata	Erosional drainage way	1993: 7,100 plants observed. 1996: Approximately 8,500 plants	SDNHP
48	N/A	Pennington	USFS Region 2 Buffalo Gap National Grassland	1993 26-Jul-1996	Agate East Allotment; approximately 7.5 miles west-northwest of Interior	On Brule/Chadron outcrops and deposition	1993: Approximately 3,000 plants observed in 1993 on 4 sites. Site 1: 42 counted in 9 sq. m; Site 2: 280 counted in 284 sq m; Site 3: 7,701 estimated; Site 4: 2,000 estimated 1996: Colonies scattered throughout a section. Approximately 13,000 plants observed on at least 7 sites [in at least 7 colonies] in 1996.	Scmoller (1993); SDNHP
49	f	Jackson	USFS Region 2 Buffalo Gap National Grassland Proposed Rake Creek Badlands Roadless Area	1993 22-Jul-1996	Weta North Allotment, Weta	Occurring in mostly barren outwash and on badland slopes. Along northwest base of Chadron/ Brule badlands butte	Approximately 3,000 plants observed in 1993, Approximately 9,000 in 1996	SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
50	f	Jackson	USFS Region 2 Buffalo Gap National Grassland Proposed Rake Creek Badlands Roadless Area, private land	1991 1993 22-Jul-1996	Weta North Allotment, approximately 5.5 miles east southeast of Cactus Flats; occurrence across three sections	Located primarily along bases of Chadron/Brule badlands mound/ butte. In mostly barren outwash from badland slopes	1991: Site 1: Approximately 500 plants. Site 2: Approximately 1,000 plants; Site 3: 30 plants; Site 4 Approximately 500 plants 1993: Approximately 500 plants 1996: 3200 plants. (Maybe overlap count with other sites).	Linabery (1991); SDNHP
51	f	Jackson	USFS Region 2 Buffalo Gap National Grassland Proposed Rake Creek Badlands Roadless AreaPrivate land [Formerly USFS Region 2 Buffalo Gap National Grassland in the proposed Rake Creek Badlands Roadless Area]	1993 22-Jul-1996	Weta North Allotment, approximately 5 miles east-southeast of Cactus Flats; Rake Creek Badlands Roadless Area	Plants occur along base of footslope and on badland exposures	1991: Site 1: Approximately 1,000 plants, Site 2: Approximately 1,000 plants 1993: Approximately 8,000 plants 1996: 18,000 plants observed.	Linabery (1991); SDNHP
52	g	Jackson	Private	Sep-1991 22-Jul-1996	Rake Creek East Allotment, approximately 10 miles east-northeast of Interior. Rake Creek Badlands Roadless Area	1996: Scattered badland mounds and outcrops of Chadron/Brule formations in mixed grass prairie matrix. In mostly barren badlands alluvium/outwash with *Eriogonum pauciflorum*, and species of *Gutierrezia* and *Grindelia*	1991: 6 plants 1996: Approximately 500 plants observed.	Linabery (1991); SDNHP
53	g	Jackson	Private [Formerly USFS Region 2 Buffalo Gap National Grassland]	06-Jul-1993	Pasture Road Ditch; approximately 9.5 miles east and 3 miles northwest from Interior	Ditch along a pasture road which drains into steep-sided waterway 4 miles away. With *Oenothera caespitosa*, and species of *Sphaeralcea* and *Melilotus*	120 plants observed in small area	SDNHP
54	N/A	Jackson	USFS Region 2 Buffalo Gap National Grassland, private land	Sep-1991 07-Jul-1993	Rake Creek watershed, 5.5 miles east northeast of Interior	Badland outcrops of Chadron/Brule formations in mixed prairie matrix. Occurs primarily on outwash at base of badland slopes	1991: Essentially two colonies, one with 250 plants, second with 200 plants 1993: 1,500 plants observed	Linabery (1991); SDNHP
55	h	Jackson	USFS Region 2 Buffalo Gap National Grassland, private land	Sep-1991	Within approximately 2 km from the Little Buffalo Creek head and 3 km from Pat Stout Dam	No information	Approximately 500 individuals	Linabery (1991)

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
56	h	Jackson	USFS Region 2 Buffalo Gap National Grassland	Sep-1991	Within approximately 2 km from McHenry Dam and approximately 3 km from Fifteen Creek head	No information	1991: Approximately 2,000 plants	Linabery (1991)
57	h	Jackson	USFS Region 2 Buffalo Gap National Grassland, private land	Sep-1991 13-Jul-1993	Badlands outcrop along upper tributary of Fifteen Creek, approximately 2 miles northwest of Weta; West Weta allotment	Brule/Chadron formation outcrops and outwash. With *Eriogonum pauciflorum* and species of *Gutierrezia* and *Salsola*	1991: 100 individuals 1993: Approximately 2,400 plants in two sub populations	Linabery (1991); SDNHP
58	h	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland]	Sep-1991 13-Jul-1993	Fifteen Creek Watershed, approximately 2 miles northwest of Weta; within one section	1991: Essentially 2 colonies: one with 110 plants and the other with 5,000 plants 1993: Colony a: Growing on 85% bare soil. Sparse grassland, 35 degree slope 1993: Colonies b: Erosional drainage ways with Brule formation mounds and outwash fans	1993: Colony a: Approximately 530 plants on Cedar Pass silt loam (?) 1993: Colonies 2: Approximately 200 plants observed in 2 locales	Linabery (1991); SDNHP
59	h	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland]	06-Aug-1986	Along Fifteen Creek north of gravel road; approximately 11 miles west-southwest of Kadoka 0.25 miles northeast of ghost town of Weta	Plants on barren slopes and outwash. Erosional features of Chadron formation. White River Group	More than 1,000 plants in localized colonies (SDNHP). Several hundred plants occurring as localized colonies (Ode 1987)	*D.J. Ode #86-66* 1986 NEB, SDC in Ode (1987); SDNHP
60	h	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland], USFS Region 2 Buffalo Gap National Grassland	Sep-1991 06-Jul-1993	Badland Butte in Upper Fifteen Creek watershed, approximately 2 miles west of Weta; survey covered two sections	Chadron/Brule formation	1991: 10 plants. Plants were observed on northeast face of butte in 1991 Area surveyed in 1993 but no plants were found.	Linabery (1991); SDNHP
61	h	Jackson	Private [Formerly USFS Region 2 Buffalo Gap National Grassland]	06-Jul-1993	Badland Butte in Upper Fifteen Creek watershed, approximately 2 miles west of Weta	Isolated badland mound/spire of Chadron/Brule formation approximately 100 ft tall. Mostly on footslope and mostly barren outwash deposits	1993: Approximately 500 plants observed	SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
62	h	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland] , USFS Region 2 Buffalo Gap National Grassland	Sep-1991	Badland Butte in Upper Fifteen Creek watershed, approximately 2 miles west of Weta	No information	1991: 100 individuals	Linabery (1991)
63	h	Jackson	USFS Region 2 Buffalo Gap National Grassland	24-Jul-1996	Weta South Allotment, Approximately 12 miles east of Interior	Scattered badland outcrops of Chadron/Brule formations in mixed prairie matrix	Approximately 20,000 plants observed at >7 locations. Majority distributed in one area	SDNHP
64	h	Jackson	USFS Region 2 Buffalo Gap National Grassland, private land	1991 1993	Weta South Allotment	Badlands	1991: Site: 1: Actual number 30 individuals; Site 2: 2000 individuals 1993: Site: 1: Zero observed	Linabery (1991); Schmoller (1993)
65	j	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland]	08-Jul-1993	Isolated Badland Buttes located near the White River approximately 9 miles east-southeast of Interior; 2 miles east of School Section Butte	Brule formation buttes/mounds with plants on erosional outwash on northwest side of Butte	10 plants observed in 1991. 349 plants observed in 1993	SDNHP
66	j	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland]	15-Jul-1993	Badland outcrops located approximately 2 miles east-northwest of School Section Butte; occurrence across two sections	1993: Chadron/Brule formation. Mounds and outcrops in grassland matrix. Plants along bases of badlands mounds	1991: 20 plants in one colony (Linabery 1991) 1993: Approximately 800 plants observed in several colonies	Linabery (1991); SDNHP
67	j	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland], privately owned rangeland	1957 Sep-1991 06-Aug-1986	Sixteen Mile Creek Badlands; 6.5 miles east southeast of Interior	Barren clay of shallow roadside cutbank and adjacent badlands breaks. White River Group formation	1986: Several hundred plants observed. No plants were found around base of flat top butte or smaller buttes north of site (1986) 1991: 150 plants in one colony (Linabery 1991)	*Lindstrom #297* 1957 SDU, Badlands National Park Herbarium; *D.J. Ode #86-65* 1986 SDC in Ode (1987); Linabery (1991); SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
68	j	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland]	Sep-1991 14-Jul-1993	Badlands Butte located along Rake Creek, approximately 7.5 miles east of Interior	Isolated cluster of Chadron/Brule formation. Badland buttes and mounds	1991: 500 plants in essentially 2 colonies 1993: Approximately 5,000 plants observed in at least 13 scattered colonies on mostly barren slopes and outwash	Linabery (1991); SDNHP
69	j	Jackson	Private land [Formerly USFS Region 2 Buffalo Gap National Grassland]	1991 15-Jul-1993	Approximately 4 miles east of Flattop Butte, approximately 10 miles east southeast of Interior	Badlands mounds and outcrops of Chadron/Brule formation. Mounds and outcrops in grassland matrix	1991: Two colonies, one with 40 plants second with 10 plants 1993: 28 plants observed in 1993	Linabery (1991); SDNHP
70	j	Jackson	USFS Region 2 Buffalo Gap National Grassland	24-Jul-1996	Flattop Butte Allotment; South pasture, approximately 6 miles east southeast of Interior; located on northwest end of School Section Butte	Along base of badland slopes, Brule formation	Number of plants observed in: 1991: 150 1993: 366 1996: 450	SDNHP
71	N/A	Jackson	USFS Region 2 Buffalo Gap National Grassland, private inholding	14-Jul-1971 06-Aug-1986	1971: Approximately 0.4 miles west of Highway 40A; approximately 2 miles east-southeast of Interior	1971: On a large grassy clay flat. Found only along minor drainages on the flat. Associated with numerous species of grasses, *Psoralea*, and *Rudbeckia* 1986: Barren mounds and outwash from White River Group	1971: No abundance information. Flowers yellowish, pubescent 1986: Less than 50 plants observed on barren clay outwash	*J.L. Reveal and C.G. Reveal #2512* 1971 KANU (also at RM in Ode (1987)); *Ode #86-64* 1986 BHSC in Ode (1987); SDNHP
72	N/A	Jackson	Badlands National Park	23-Jul-1913	Cedar Pass	Dry steppe	[Area] presently located in Badlands National Park - despite repeated attempts [occurrence] not been found (Ode 1987)	*W.H. Over #B202* 1913 SDU; SDNHP

Table 1 (cont.).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
73	N/A	Mellette	Privately owned rangeland with inholding of the Rosebud Sioux Tribe	13-Jul-1971 22-Aug-1971 11-Aug-1984 27-Aug-1987	Jul-1971: 9.5 miles west of Wood Aug-1971: 9.5 miles west of Wood 1984: Little Badlands south of Mellete Mountain; approximately 9.7 miles west of Wood along Highway 44, 5 miles southeast of White River; badland outcrops approximately 0.5 miles south of Highway 44 1987: 4 miles east of junction between Highways 83 and 44, south of 44; occurrence across three sections	July and August 1971: Eroded prairie, near hilltop. Rocky, clay soil 1984: On barren clay slopes, washes, and ridges with *Mentzelia*, *Kochia*, *Astragalus racemosus*, *Cryptantha*, and *Dalea enneandra*. Apparently White River [formation] 1987: Badlands area, growing on barren clay slopes and outwash of eroding badland formations	July and August 1971: Abundant 1984: Locally abundant 1987: Small localized population 1987: In flower	*S. Stephens #49311* July 1971 MARY, KANU; *S. Stephens #51490* August 1971 MARY, KANU; *D.J. Ode #84-144* 1984 SDC, SDU in Ode (1987); *J.H. Locklear #120* 1987 KANU (duplicate sheets); SDNHP
74	N/A	Pennington	Privately owned rangeland	08-Jun-1970 16-Jul-1971 11-Jul-1982 05-Aug-1986	1970: 29 miles east of Scenic 1971: 29 miles east of Scenic, 1 mile west of county line 1982, 1986: North side of Highway 44 approximately 29 miles southeast of Scenic, 3.25 miles west of Interior; Buckwheat curve along Highway 44; occurrence across two sections	1970: Flat prairie. Rocky gravel clay soil 1971: Badlands area [plants] at base of clay butte in alluvial clay, sandy. Plants on mostly barren clay mounds and outwash along the base of a long narrow badlands mound. Interior phase of the Pierre formation	1970: Few plants 1971: Few plants 1986: More than 1,000 plants as localized colonies.	*S. Stephens and R.E. Brooks #39311* 1970 KANU; *R.E. Brooks #2238* 1970 SDC; *S. Stephens #49497* 1971 KANU; *D.J. Ode #82-52* 1982 SDC, SDU in Ode (1987); SDNHP
75	N/A	Pennington	USFS Region 2 Buffalo Gap National Grassland	17-Jun-2005	Approximately 3 miles southwest of Kadoka north on highway CH 6	On a badlands clay shelf sloping into a deep-cut drainage, soils are heavy white clay. Elevation approximately 2,038 feet	20-50 plants	Kostel (2006)
76	N/A	Pennington	USFS Region 2 Buffalo Gap National Grassland	20-Jun-2005	Approximately 5 miles southeast of Wall	Flat to rolling grass uplands draining into clay basin floodplains; soils are sand and silt on uplands to heavy clay in basin bottoms. Elevation approximately 2,178 feet	20-50 plants	Kostel (2006)

Table 1 (concluded).

SD - No.	Occurrence association[1]	County	Land Management[2]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[3,4,5]
77	N/A	Pennington	USFS Region 2 Buffalo Gap National Grassland	20-Jun-2005	Approximately 6.5 miles southeast of Wall	Flat to rolling grass uplands draining into clay basin floodplains; soils are silt and sand on uplands and heavy clay in basin bottoms. Elevation approximately 2,189 feet	20-50 plants	Kostel (2006)

[1]Occurrence association: Occurrences with the same letter are potentially sub-occurrences within a larger area. There is no information to suggest that occurrences marked N/A are anything other than isolated from each other.

[2]NG abbreviation for National Grasslands.

R1 = USDA Forest Service Region 1

R2 = USDA Forest Service Region 2

[3]When specimens could not be located at a specified herbarium, the collection information is reported and its source indicated. For example "*D.J. Ode #86-72* BHSC in Ode (1987)" means that this collection was reported in the publication Ode (1987). For this report only one specimen (*D.J. Ode #86-90* 1986) was located at BHSC and none could be located at the Bessey Herbarium (NEB).

[4]Herbaria abbreviations:

BHSC = Black Hills State University, Spearfish, South Dakota

DWU = Dakota Wesleyan University, Mitchell, South Dakota

F = Field Museum of Natural History, Chicago, Illinois

GFND = University of North Dakota Herbarium, Grand Forks, North Dakota

KANU = R.L. McGregor Herbarium, University of Kansas, Lawrence, Kansas

MONTU = University of Montana Herbarium, Montana

NEB = C. E. Bessey Herbarium, University of Nebraska State Museum

PH = The Academy of Natural Sciences, Philadelphia, Pennsylvania

SDC = South Dakota State University Herbarium, Brookings, South Dakota

[5]SDNHP = South Dakota Natural Heritage Program (2005).

Table 2. Occurrences of *Eriogonum visheri* in Montana and North Dakota.

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
MT 1	N/A	Carter	Bureau of Land Management. Miles City Field Office	06-Jun-1997 12-Jul-1997	Powderville Road badlands, approximately 17 miles west southwest of Ekalaka	Sparsely vegetated outwash flats below eroding bentonite badland slopes in the Hell Creek formation dominated by *Atriplex confertifolia* and *Artemisia tridentata*. Density of *Musineon divaricatum* and *Allium textile* is very high. Other associated species include: *Agropyron dasystachyum*, *Sitanion hystrix*, *Sarcobatus vermiculatus*, *Krascheninnikovia lanata*, *Oryzopsis hymenoides*, *Oenothera caespitosa*, and *Atriplex suckleyi*. Substrates are vesicular silt. Elevation 3,000 ft. to 3,140 ft.	June 6 1997: Over 100 plants in two separate outwash fans. Reproduction appears good-excellent around last year's parent plants. Flowering barely began 06-Jun-1997: Extent of population undetermined 12-Jul-1997: Further exploration of vicinity; approximately 1,000 plants in 4 subpopulations, 100% in flower. Light, infrequent grazing Size: 0.72 acres in 40 acres	*B. Heidel and S. Cooper #1540* June 1997 MONT; *J. Vanderhorst #5732* July 1997 MONTU; Montana Natural Heritage Program (2005)
ND 1	a	Sioux	Standing Rock Tribal Land	22-Jul-1982	East of Highway 31, approximately 7 miles north of McIntosh Lake	Sand/clay wash area and along base of south facing cliff	Locally rare	North Dakota Natural Heritage Inventory (2005)
ND 2	a	Sioux	Standing Rock Tribal Land (and/ or Private and State ?)	22-Jul-1982	East of Highway 31, approximately 5.5 miles north of McIntosh Lake	Sub-occurrence A: On outwash around base of isolated butte. Sub-occurrence B: Clay/sand wash	Sub-occurrence A: Locally common Sub-occurrence B: Locally rare	North Dakota Natural Heritage Inventory (2005)
ND 3	a	Sioux	Standing Rock Tribal Land (and/ or State ?)	22-Jul-1982	East of Highway 31, approximately 4.5 miles north of McIntosh Lake	North drainage, shallow wash	Locally common	North Dakota Natural Heritage Inventory (2005)
ND 4	a	Sioux	Standing Rock Tribal Land	18-Jul-1971	East of Highway 31, approximately 3.5 miles north of McIntosh Lake	Base of eroded prairie bluff, gravel clay soil	Abundant	North Dakota Natural Heritage Inventory (2005)
ND 5	a	Sioux	Standing Rock Tribal Land	18-Jul-1971	Approximately 3 miles north of SD state line on Highway 31	Base of eroded prairie bluff. Gravel, clay soil	Abundant	*S. Stephens #49559* KANU
ND 6	b	Grant	Private	18-Jul-1971 24-Aug-1983	1971: 15 miles south of Raleigh 1983: Bell Coulee East Quadrangle	1971: Base of clay prairie bluff. Sandstone soil 1983: Base of cliff in northwest corner of bay, in small patches on mounds covered by limonite pebbles	1971: Few plants 1983: A few dense patches plus one plant along the cliff base to the west 1983: Most of this area maybe too sandy [to support *Erigonum visheri*]	*S. Stephens #49560* 1971 KANU; North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 7	b	Grant	Private	22-May-1982 (MARY) 22-July-1982 (GFND) 23-Aug-94	1982: 1.2 miles north [of] Cannonball River just west of Highway 31	1982: On limonite gravel. On sand/ clay outwash along base of cliff 1994: Base of clay bluff in prairie, sandstone, clay or black pebble outwash, mostly restricted to clay hardpan and/or limonite pebbles over clay. “Exposed badland slopes, south and southwest aspect. Tops of badlands covered with grass. Small to medium sized alluvial fans with sandy soil. Sparse vegetation.” 70% bare ground	1982: Locally common. Plants in several colonies. One very dense colony about 10 ft square area. Very small plants on limonite gravel 1994: Many plants found, small plants occur on limonite pebbles over clay. Approximately 400 individuals distributed through approximately 10 acres. Individuals are grouped in alluvial areas where badland soils are outwashed. 20% vegetative, 80% flowering or in fruit. No disease of herbivory noted. Some plants appear to be desiccated	*R. Warner #1070 1982* MARY, GFND; *R. Warner #1071* 1982 MARY; Lenz (1995); North Dakota Natural Heritage Inventory (2005)
ND 8	N/A	Grant	Private	29-Jun-1907	Wade [on the Cannonball River]	Hillside	No information	*W.B. Bell #233* F; North Dakota Natural Heritage Inventory (2005)
ND 9	N/A	Grant	Private	08-Aug-1952	Approximately 2.5 miles north east of Lookout Butte and approximately 13 miles north of the state line	With *Iva axillaris* on black clay butte, north slope	No information	North Dakota Natural Heritage Inventory (2005)
ND 10	c	Grant	Private	24-Aug-1983	Approximately 1 mile east of Carson Road, south of the Cannonball River and approximately 9 miles north of the boundary of the Standing Rock Tribal lands	Mixed grass prairie (?), Clay outwash areas with *Distichlis* and other xeric/alkali-loving species	Locally abundant and possibly very wide spread	North Dakota Natural Heritage Inventory (2005)
ND 11	c	Grant	Private	26-Aug-1994	Approximately 0.75 mile east of Carson Road, south of the Cannonball River and approximately 9 miles north of the boundary of the Standing Rock Tribal lands	Blow out or alluvial erosion on broad, flat plain producing areas of varying size which have sandy-clay soils. Dry, approximately 70% bare ground	Approximately 200 individuals distributed over approximately 10 acres. 10 % vegetative, 90% in fruit or flower. Consists of many subpopulations. Some plants appear to be desiccated	Lenz (1995); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 12	N/A	Slope	Private	11-Sep-1992	Vicinity of Marmarth Road and North Butte Creek intersection	Clay outwash flats below a small clay dome. Plants mostly in concentrations along the edge of outwash areas and on small side, gravel piles and at the head of a small drainage. Sparse vegetation includes *Eriogonum pauciflorum*, species of *Sarcobatus*, *Gutierrezia*, *Grindelia*, and *Machaeranthera*	Approximately 150-200 plants	North Dakota Natural Heritage Inventory (2005)
ND 13	N/A/	Slope	Private	11-Jul-1995	Vicinity west of Marmarth Road and north of Pretty Butte	No information	No information	North Dakota Natural Heritage Inventory (2005)
ND 14	d	Slope	USDA Forest Service (USFS) Region 1 Little Missouri National Grassland	16-Sep-1993 1994 01-Jul-1997 25-Sep-2001 26-Sep-2001 26-Jul-2003	Off Forest Route 769, approximately 4.5 miles from its intersection with Forest Route 7695 in the vicinity of the “last buffalo hunt in North Dakota” (USDA Forest Service 2000)	1993: Population adjacent to road, and between road and old trail near the base of a badlands landform in a clay outwash community, clay substrate with clay/gravel surface (Vanderpool 1993). The base is covered with scoria gravel over 80% bare-ground. Bounded by a badlands landform to the east and small hills to the west 1993b: “Small badlands clay butte with associated outwash area. Sparsely vegetated.” 1994: “Dry badland, medium sized alluvial fans at base of badlands formation, 80% Bare ground.” 1997: Associated with saltbrush community, *Agropyron smithii*, blue grama 2001: Sub-occurrence A: In open xeric site on 6% slope and south aspect. 50% bare soil and 40% rock cover. Bentonite outcrops. Sub-occurrence B: On xeric open barren clay soils with a lot of surface sandy wash, 0-3% slopes. Sub-occurrence C, D: Nearly level (continue next page)	1993: Approximately 100,000 individuals in an area approximately 75 ft wide [unreported length] 1994: “Roughly 250 individuals found on exposed badland slopes and talus outwash on south and west aspects with roughly 80% bare ground. Grazed area. Heavy erosion in alluvial fans and in small intermittent drainages.” 1997: Population over 5-8 acres; First plot had 60 individuals. “Approximately 100 individual *E. visheri* scattered randomly along sides of the cattle path.” “Habitat limited to barren clay outwash areas. Sparsely vegetated area. 100 plus individuals in two small patches covering less than an acre. Normal vigor.” 2001: Sub-occurrence A: Plants occur as one main cluster, with a few scattered plants. 68 plants in an area of 25x5 ft. Sub-occurrence B: A total of (continue next page)	Vanderpool (1993); Diller (2002); Lenz (2003); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 14	d	Slope	USDA Forest Service (USFS) Region 1 Little Missouri National Grassland	16-Sep-1993 1994 01-Jul-1997 25-Sep-2001 26-Sep-2001 26-Jul-2003	Off Forest Route 769, approximately 4.5 miles from its intersection with Forest Route 7695 in the vicinity of the "last buffalo hunt in North Dakota" (USDA Forest Service 2000)	southern or eastern exposure clay area, 90% barren or covered by up to 100% scoria and other rocks. Sub-occurrence C receives runoff from the clay butte and from a scoria-surfaced road. Much of the area has been substantially disturbed 2001: Exotics in the area include *Agropyron cristatum*, *A. intermedium*, *Melilotis officinalis*, and *Salsola iberica*. *Agropyron cristatum* most dominant, probably because it was seeded in association with old disturbances 2003: Bare ground surrounded by grassland. Relatively pure stand of *A. cristatum* to south of sub-occurrence 1	>21,500 plants in at least 4 colonies; colony 1: 13,266 plants, 2: 4,589 plants, 3: 2,975 plants, 4: 750 plants. These larger colonies can be seen to be divided into smaller colonies of 37 to 300 individuals. Sub-occurrence C: 1,650 individuals, most within 50 ft of the County road. Sub-occurrence D: two colonies each approximately 100x40 ft; colonies 1: 445 plants, 2: 383 plants 2001: Sub-occurrence A: Light grazing, a cow trail runs along edge of the population. Sub-occurrence B: Light grazing, cattle trails occur. General area has been mined for scoria in the past. Plants are at the far edge of a sandy wash. Those in the "bowl are more numerous, "very dense" but smaller. Sub-occurrence C: Light grazing. Much of the area has been substantially disturbed; an old borrow pit lies in the northeast portion. Several non-native weedy species occur in the populations and portions of the north have been seeded with *Agropyron cristatum*. Weedy species include *Salsola iberica* and *Melilotus officinalis*. Some plants will be affected by County road maintenance. Sub-occurrence D: Light grazing. Plants near an old cow trail and (continue next page)	Vanderpool (1993); Diller (2002); Lenz (2003); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 14	d	Slope	USDA Forest Service (USFS) Region 1 Little Missouri National Grassland	16-Sep-1993 1994 01-Jul-1997 25-Sep-2001 26-Sep-2001 26-Jul-2003	Off Forest Route 769, approximately 4.5 miles from its intersection with Forest Route 7695 in the vicinity of the "last buffalo hunt in North Dakota" (USDA Forest Service 2000)		erosion cuts. *Salsola iberica* in small numbers. Sub-occurrence E: Much of the area has been substantially disturbed in the past; a scoria pit is to the north 2003: 32 individuals in bud at a density of approximately 5 per sq. ft; individuals are less dense on the edges of the bare areas 2003: Sub occurrence 1: 32 individuals in approximately 60 square ft. Sub-occurrence 2: Approximately 617 individuals scattered on 4 groups within approximately 1,620 square ft. Approximately 75-80% in bud; rest in flower	Vanderpool (1993); Diller (2002); Lenz (2003); North Dakota Natural Heritage Inventory (2005)
ND 15	d	Slope	USFS Region 1 Little Missouri National Grassland	24-Aug-1993 25-Aug-1993 25-Sep-2001	Along Forest Route 769, less than 4 miles from its intersection with Forest Route 7695, in vicinity of Scoria Pit. 1n 1993: occurrence extended across 2 sections	1993: Site 2 (August 24): Occurs on clay outwash of a badlands formation. Over 80% bare soil. Bounded by a small ravine on the west and badland landforms on the east. Site 3 (August 25). Population is bounded by a badlands landform on the east and small rolling hills on the west. Population occurs on flat clay outwash on west side of badlands landform. There is over 80% bare ground present 2001: Three sub-occurrences; Sub-occurrence A: Plants are scattered on the clay pan spots, no plants on butte. In clay areas of 3-5% slopes with east aspect. Plants mid-slope. High residual vegetation cover occurs on grasslands between pan spots. Pan spots may have up to 35% vegetation cover. Sub-occurrence receives runoff from a (continue next page)	1993: Site 2: Approximately 300-400 individuals spread over an area of approximately 200 ft by 40 ft plus a small 0.1 acre circle on west side of road and a small 0.1 acre patch near the fence on the east. Site 3: Approximately 570 individuals, approximately 40 spread out on the north side of the site and a dense clump of approximately 500 a little to the south with a few more scattered farther to the south and approximately 20 in a clump on the northeast side of the landform.." 2001: Sub-occurrence A: >460 plants in an area of 150x100 ft. Sub-occurrence B: Approximately 1,600 plants in a "U"-shaped area of 400x100 ft. Sub-occurrence C: 858 plants (continue next page)	Lenz (1995); Diller (2002); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 15	d	Slope	USFS Region 1 Little Missouri National Grassland	24-Aug-1993 25-Aug-1993 25-Sep-2001	Along Forest Route 769, less than 4 miles from its intersection with Forest Route 7695, in vicinity of Scoria Pit. 1n 1993: occurrence extended across 2 sections	scoria butte that occurs approximately 200 ft west of the area with the plants. Sub-occurrence B: On exposed clay breaks near a clay knob that provides runoff. Plants upland on 3% slopes with primarily northwest aspect, 90% barren with <10% scoria and other rock cover. Sub-occurrence C: Plants scattered in clusters and as isolated individuals. Plants upland on level ground with south aspect in open xeric conditions; 90% barren with no rock cover. Receives runoff from clay knobs in area	2001: Light cattle grazing, some cattle trails. General area used for scoria mining. Sub-occurrence A: For no obvious reason, i.e. no difference in habitat conditions, *Eriogonum visheri* were not found in all the pan spots. No non-natives were noted. Sub-occurrence C: Some *Salsola iberica* present	Lenz (1995); Diller (2002); North Dakota Natural Heritage Inventory (2005)
ND 16	e	Slope	USFS Region 1 Little Missouri National Grassland	22-Sep-1993 26-Sep-2001	North of Forest Route 769, northwest of its intersection with Forest Route 7695	1993: Small clay butte with outwash area. Habitat was limited to sparsely vegetated clay outwash areas. 2001:Plants on barren clay with up to 40% rock cover, 6% slope with northwest aspect. Slope receives runoff from clay buttes in area	1993: "Population covered less than half an acre. Approximately 25 individuals in two groups. Plants had set seed, some were senescent. Normal vigor 2001: Total 183 plants in four main portions of a 10 acre area. Area 1: 4x4 ft, 2: 10x5 ft, 3: 10x10 ft and 4: 1x8 ft. Plants tend to be around the perimeters of each area 2001: Light grazing. Natural erosion. Population lies near a county road. *Melilotis officinalis* and *Salsola iberica* are in the area. Buttes north of the plant sites were surveyed but no other colonies located	Diller (2002); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 17	e	Slope	USFS Region 1 Little Missouri National Grassland	16-Sep-1993 26-Sep-2001	24 miles south of Belfield and 6.5 miles west on Forest Road 769; *Eriogonum visheri* on side of dam southeast of dam and adjacent to fence	1993: Population is sandwiched between steep slope and grassland vegetation. Clay outwash community on flat to low relief clay outwash just below eroded hill. Clay substrate with clay/gravel surface. (Vanderpool 1993) 2001: Two sub-occurrences located in 2001. Sub-occurrence A: Plants near the top of a hill with no plants found downslope. 15% slope with northeast aspect, clay soils, 90% barren with 5-25% limonite. Sub-occurrence B: On the upland terrace above Second Creek on slopes of 0-15% with north (colonies 1and2) or south southeast (colony 3) exposures. 90% barren clay soil with 10-30% limonite	1993: Total basal [vegetation] cover approximately 15%, *Eriogonum visheri* basal cover approx. 0.5%. Estimated 9,000 individuals (Vanderpool 1993). Subsite A: 6,655 individuals, Subsite B: 2,318 individuals, Subsite C: 135 individuals. Plants 2 to 8 inches tall. Mainly with seeds curing out, reddish. Total basal coverage of all clay outwash area = 15%; basal coverage of *E. visheri* on clay outwash less than 0.5%. Site 1: Subsite A: 2,484 individuals, Subsite B: 195 individuals, Subsite C: 210 individuals Subsite D: 9,600 individuals. Scattered clumps and individuals around ridge 2001: Sub-occurrence A: Approximately 320 plants in dense clusters or scattered in an area 75x10 ft. Sub-occurrence B: Total 615 plants in three colonies; 1: 48 plants in 5x30 ft area, 2: 31 plants in 30x10 ft area, 3: 535 plants in 100x15 ft area.1993: Small dam at bottom of slope and at least one cattle trail leading down to it. Area in a state of constant erosion. Fence near subsite C. (Vanderpool 1993) 2001: Sub-occurrence A: Light grazing. Plants most common along cow trail. Sub-occurrence B: Light grazing. Colonies 2 and (continue next page)	Lenz (1995); Diller (2002); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 17	e	Slope	USFS Region 1 Little Missouri National Grassland	16-Sep-1993 26-Sep-2001	24 miles south of Belfield and 6.5 miles west on Forest Road 769; *Eriogonum visheri* on side of dam southeast of dam and adjacent to fence		3 are dissected by a fence line. Colony C has active headcutting adjacent to the plants. *Melilotis officinalis* and *Salsola iberica* are in the area	Lenz (1995); Diller (2002); North Dakota Natural Heritage Inventory (2005)
ND 18	e	Slope	USFS Region 1 Little Missouri National Grassland	Aug-1992 26-Sep-2001	Approximately 1.5 miles west of Forest Route 769 and 1.5 miles east of BM 2744 (836)	1992: A drainage way surrounded by badlands and clay outwashes 2001: Plants on upland terrace and are most common along grass margins and micro-drainages on 0-6% slopes with in open xeric conditions. Colony A on clay with >80% scoria cover with southwest aspect. Colony B on barren clay soils with 0-10% rock cover and south aspect	1992: Approximately 50 individuals at lower ridge of badlands landform, 85% bare soil 2001: Plants are as isolated individuals or scattered in clusters. Total 98 plants in two main colonies. 1: 51 plants in 18 (3x6) sq. ft area; 2: 47 plants in 200 (10x20) sq. ft area. Light grazing. Uplands grasslands dominated by *Agropyron smithii* and *Bouteloua gracilis*. *Salsola iberica* occurs in area	Burger s.n. 1992 deposited with USFS Medora Office; Diller (2002); North Dakota Natural Heritage Inventory (2005)
ND 19	N/A	Billings	State	20-Sep-1992	1.5 miles north of intersection between Forest route FH3 and Forest route 746	Small hollow atop a divide, between small scoria knolls. In small deflated clay flats with sparse vegetation. Associated species: *Grindelia squarrosa*, *Distichlis stricta*, *Suaeda calceoli formis*, and *Iva axillaris*	Approximately 70 plants, in flower as of 17 August	North Dakota Natural Heritage Inventory (2005)
ND 20	N/A	Billings	USFS Region 1 Little Missouri National Grassland	01-Jul-1997 08-Sep-2001	Approximately 2.5 miles south of intersection between Forest route 739 and Forest route 763	1997: Alluvial flat surrounded by hills. *Distichlis spicata*, *Gutierrezia sarothrae*, and *Artemisia canescens* 2001:Sub-occurrence A [Likely to be a different site than that observed in 1997]. Open, xeric, barren clays with 0-1% slope. Plants associated with slight drainage on erosion breaks. A clay butte occurs to the south but no plants near it. Sub-occurrence B: (continue next page)	1997: Colony sizes: northwest pan 500, southeast pan 1,000 2001: Sub-occurrence A: Approximately 2,300 in 1000x250 ft area. Sub-occurrence B, Colony 1 approximately 150 plants in a 10x20 ft area; colony 2 approximately 350 plants in a 10x200 ft area. 2001: Occurrences in an (continue next page)	North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 20	N/A	Billings	USFS Region 1 Little Missouri National Grassland	01-Jul-1997 08-Sep-2001	Approximately 2.5 miles south of intersection between Forest route 739 and Forest route 763	Open xeric barren clays with >80% bare soils and 0-3% slope. Two colonies. Colony 1in area along a road that appears to have been inundated [with water?] earlier in the year. Colony 2 associated with the edge of a drainage that runs through a large clay flat; plants occur in a minor secondary drain and around an area of active head cutting	active oilfield. Light grazing. Sub-occurrence A: *Melilotis officinalis* occurs in area. Colonies dissected by a pipeline right-of-way and an oil well access road. Plants grow on the pipeline route. The 2001 sub-occurrence A was originally discovered while conducting a survey for a proposed salt water line. Although an intensive survey was not made in 1994 it appears more plants were present in 2001 (Diller 2002). Sub-occurrence B: *Kochia scoparia* occurs in the area	North Dakota Natural Heritage Inventory (2005)
ND 21	N/A	Golden Valley	Private	08-Jul-1989 09-Jul-1989	Northwest of St. Michaels Cemetery (near Sentinel Butte) in vicinity of Custer's Historic trail	Southerly facing clay slope and benches with minimal vegetation cover. Associated species: *Ceratoides lanata*, *Iva axillaris*, *Distichlis stricta*, and *Stipa comata*	Over 500 plants. Found in four areas. Highly variable plant densities. In flower 9 June 1989	*Wieland #5153* 18-Jul-1989 GFND (2 specimen sheets); North Dakota Natural Heritage Inventory (2005)
ND 22	N/A	Billings	USFS Region 1 Little Missouri National Grassland	26-Sep-1997	East of the Maah Daah Hey Trail within 1 mile of the boundary of the Theodore Roosevelt Wilderness (south unit)	No information	1997: 50 plants within 0.5 acre	North Dakota Natural Heritage Inventory (2005)
ND 23	f	Billings	USFS Region 1 Little Missouri National Grassland	1993 11-Jul-1997 12-Sep-2001	South and southeast of Buffalo Gap Trail that is north and east and in vicinity of Knutson Creek Substation	1993: "Site dominated by clay outwash, sparse vegetation. Approximately 7% of slope, scoria gravel on the surface. Badlands site - dry, cracked clay, shale substrate. Small knob on uplands surrounded by mixed grass prairie." 1997: Clay pan surrounding badlands knob 2001: In xeric, open barren clay with up to 60% limonite. Saline soils	1993: Several sub-occurrences. Approximately 130 plants scattered around base of little knob. All plants in flowering stage, many flowers. "Approximately 40 plants" [in another patch]) 2001: 672 plants counted in 80 ft by 70 ft area 2001: Some plants are pedestalled with basal leaves (continue next page)	

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 23	f	Billings	USFS Region 1 Little Missouri National Grassland	1993 11-Jul-1997 12-Sep-2001	South and southeast of Buffalo Gap Trail that is north and east and in vicinity of Knutson Creek Substation		2 inches or more above the ground. Some plants have been broken, presumably by the wind. Area used for livestock grazing. *Euphorbia esula* observed in a roadside ditch. Site near a county road and might be impacted by future road upgrades	Diller (2002); North Dakota Natural Heritage Inventory (2005)
ND 24	f	Billings	USFS Region 1 Little Missouri National Grassland	22-Sep-1993 11-Jul-1997	Occurrence over 1.5 sections: south, southeast and north of Buffalo Gap Trail that is north, west and in vicinity of Knutson Creek Substation	1993: On clay outwash community in clay outwash below badlands formation. Clay substrate with clay/gravel surface. (Vanderpool 1993) Habitat is bounded by steep slopes and established grasslands. Aspect 176 degrees - South., relief fairly smooth with 5% slope, xeric site conditions 1997: Associated plant species - *Puccinellia nuttalliana*, *Oenothera caespitosa*	1993: Basal cover of entire outwash area approximately 10%, basal cover of *Eriogonum visheri* approximately 0-1%. Approximately 66,000 individuals in populations. 1993: Area heavily impacted by cattle. "Cowpath and numerous signs of cattle in Subsite A, with fenceline adjacent." plants 2-6 inches tall, most curing out, reddish and still with seeds."	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)
ND 25	g	McKenzie	USFS Region 1 Little Missouri National Grassland	30-Sep-1993	Vicinity east of Forest route 876 and Forest route 801 intersection, toward Prairie Dog Creek. Occurrence across 2 sections (Survey area likely overlapped much of that in 2001, #26 below)	1993: Plants in many sub-occurrences and subsites that in turn are composed several colonies. Substrate is clay with a clay/gravel surface. Plants on outwash at base of low hills, along a small ridge or saddle of bentonite, bentonite slump, disturbed areas of clay and gravel surface, usually in clay outwash at base of clay slope. All colonies bounded by established grassland vegetation. Sites are generally xeric and exposed	1993: Extensive site with numerous scattered colonies. Extensive development of colonies along a scoria road. At least 9 colonies at one sub-occurrence (distinguished as sites A-I by surveyor) totaling approximately 20,000 individuals. At another sub-occurrence (several colonies): approximately 1,100 individuals total	Vanderpool (1993); Diller (2002); North Dakota Natural Heritage Inventory (2005)
ND 26	g	McKenzie	USFS Region 1 Little Missouri National Grassland	21-Sep-2001	2001: Vicinity northwest of Forest route 876 and Forest route 801 intersection. (Survey area likely overlapped much of that in 1993, #25 above)	2001: Plants on butte tops, butte bases and erosion cuts up to approximately 100 ft from the buttes. Plants in clay, often with a surface sandy wash, from >80% (continue next page)	Approximately 2,100 plants in 3 colonies: Colony E 355 plants, Colony G with 1,600 plants and Colony F with 150 plants. Colony E is divided in two areas (continue next page)	Diller (2002)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 26	g	McKenzie	USFS Region 1 Little Missouri National Grassland	21-Sep-2001	2001: Vicinity northwest of Forest route 876 and Forest route 801 intersection. (Survey area likely overlapped much of that in 1993, #25 above)	bare ground to up to 80% rock cover and with slopes 0-10%. Aspects west and east	a group of approximately 35 plants occur in a small erosion cut approximately 15 ft from a wooded draw on the toe slope. Plants also occur on the top of the butte in a bowl (50 ft diameter). Colony F occurs around a clay mound area of approximately 50 ft across with some plants occurring in a small butte saddle. Colony G can be subdivided into at least 3 discrete patches: 1) Plants occur in patches at various intervals for approximately 250 ft. 2) Plants occur on a narrow, 10x3 ft area at the east side of the butte. 3) Plants are on the top of the butte	Diller (2002)
ND 27	g	McKenzie	USFS Region 1 Little Missouri National Grassland	20-Aug-2001	2001: Vicinity northwest of Forest route 876 and Forest route 801 intersection. (Survey area likely overlapped that in 1993, #25 above and #28 below)	2001: Sub-occurrence 1: Plants on toe slope, pan areas, edge of breaks, 0% slope, south aspect, on clay with 90-95% rock cover. Area receives runoff from clay buttes. Sub-occurrence 2: Most plants grow on erosion breaks downslope from the buttes. Plants midslope, butte base and on a pond embankment. Slopes 0-3% with south-southwest aspect on barren clays. some areas with relatively deep sandy wash on the surface. Bare ground >80%.One colony (A) on a manmade embankment of a dugout [pond]. Sub-occurrence 3: Plants are associated with a residual clay butte in areas which receive runoff on barren clays with > 80% bare ground to up to 80% rock (limonite) cover on slopes (continue next page)	2001: This occurrence likely overlaps ND 25 and 28. Sub-occurrence 1: In 2001, no plants were found at locations that were likely where colonies A, B, C and D were described in 1993. Plants were found between original C and D colonies: 150 plants total in at least 2 colonies; 1: 80 plants in 10x10 ft area; 2: 70 plants in 5x30 ft area. Sub-occurrence 2: Approximately 1,515 plants in total in at least 4 colonies; colony A 250 plants in 50x15 ft area, B 1,200 in 300x300 ft area, C 55 in 30x2 ft area and 10 in 30x50 ft area. Sub-occurrence 3: Two colonies D and D2. 550 plants in D, which is a large area and 120 in D2 in 10x10 ft. No plants were (continue next page)	Diller (2002)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 27	g	McKenzie	USFS Region 1 Little Missouri National Grassland	20-Aug-2001	2001: Vicinity northwest of Forest route 876 and Forest route 801 intersection. (Survey area likely overlapped that in 1993, #25 above and #28 below)	0-10%. Aspect of colony D is west, that of D2 east. Sub occurrence 4: Similar to Sub-occurrence 3 except plants also found on the toe slope and found growing on [clay] pan edges	found in a third area (E) that had plants in 1993. Sub occurrence 4: Two colonies B and C. 10 plants in B in 5x10 ft area and 150 plants in C in 100x50 ft area. No plants were found in a third area (A) that had plants in 1993. *Salsola iberica* common at pond embankment area. *Kochia scoparia* is abundant on the west side of the pond embankment where *Eriogonum visheri* is absent. Cattle impact around impoundment, light to intermediate levels of grazing elsewhere. Dense grass cover occurs on the downslope side of the cow trail that occurs at the edge of the D2 colony of Sub-occurrence 3. A stock tank is in the vicinity of sub-occurrence 4. Light grazing in immediate vicinity of plants moderate to east of the colonies	Diller (2002)
ND 28	g	McKenzie	USFS Region 1 Little Missouri National Grassland	28-Sep-1993 27-Sep-1993	Vicinity west of Forest route 876 and Forest route 801 intersection. Occurrence across 2 sections (May overlap #27 with previous occurrence)	Plants in several sub-occurrences that in turn are composed several colonies. Sub-occurrence 1: Clay outwash community with a clay/ gravel surface. *Eriogonum visheri* at the base of low relief hills with exposed clay sides. Sub occurrence 2: Clay outwash community with clay substrate a clay/gravel surface. One colony is found on the downstream side of a stock pond dam on the draw. Sub occurrence 3: Clay outwash community with clay substrate a clay/gravel surface.	Plants in several sub-occurrences that in turn are composed several colonies. Sub-occurrence 1 has at least 9 colonies (distinguished as sites A-I by surveyor) totaling approximately 31,000 individuals. Sub occurrence 2: approximately 1,000 individuals. Sub occurrence 3 approximately 6,000 individuals. Well-traveled oil well roads nearby. Appears to have been fairly vigorous this season due to the height of most plants in this site”	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)

(continue next page)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 28	g	McKenzie	USFS Region 1 Little Missouri National Grassland	28-Sep-1993 27-Sep-1993	Vicinity west of Forest route 876 and Forest route 801 intersection. Occurrence across 2 sections (May overlap #27 with previous occurrence)	*E. visheri* found at the base of low relief hills having exposed clay sides and extending up slopes to 5 ft above outwash plain		Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)
ND 29	g	McKenzie	USFS Region 1 Little Missouri National Grassland	21-Sep-2001	2001: Vicinity north and south of Forest route 876 and Forest route 801 intersection. Survey area likely overlaps with portions of the 1993 #28 (immediately above) and #30 (below)	Plants scattered in cluster and as isolated individuals on midslope, butte base and butte terraces. Sub-occurrence A: Slopes 0-3% with south-southwest aspect on barren clays, some areas with relatively deep sandy wash on the surface; > 90% are ground. Four colonies associated with small residual buttes and small erosional features in the area. Sub-occurrence B: The majority of plants occur along an outcrop of limonite that occurs as a depositional layer in the buttes and exposed on the butte tops. Plants are "quite vigorous in these areas." Plants on barren clays on slopes 0-10% with >80% bare soils to up to 100% rock (mostly limonite) cover	Sub-occurrence A: Four colonies 941 plants total. Colony A 15 in area 5x10 ft area within an area of 150x150 ft similar habitat. B 424 in 80x300 ft area. C: 300 in 20x10 ft area. D: 202 plants in 100x100 ft area. Sub-occurrence B: >4,000 plants around a butte ridge in at least 5 colonies (likely more) an area of approximately 2,500x500 ft. Plants were concentrated along terraces on the butte sides, but some were clustered on the lips of the buttes, on the butte tops and in the wash areas below the buttes. Light grazing by cattle. Sub-occurrence B: This is a very steep area; the butte ridge walls approximately 50 ft high. The area is inaccessible to vehicles	Diller (2002)
ND 30	g	McKenzie	USFS Region 1 Little Missouri National Grassland	28-Sep-1993	Vicinity south and southwest of Forest route 876 and Forest route 801 intersection	Barren clays, some with relatively deep sandy wash on the surface and >80% bare ground. Sub-occurrences are A: Plants in saddle area between buttes on 0-6% slopes, some with south, north and open aspect. B: Plants at base of residual clay butte on 0-3% slopes, some with southern aspect. C: Plants at base of residual clay butte on 0-3% slopes, some with (continue next page)	Plants scattered in clusters or as isolated individuals. Estimated sub-occurrence sizes are A: Approximately 6,000 plants scattered in dense clusters or isolated individuals; B: 320 plants in approximate 250x75 ft area; C: 100 plants, D: 8 plants; E: no data; F: approximately 4,000 individuals total. G: approximately 900 individuals (continue next page)	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 30	g	McKenzie	USFS Region 1 Little Missouri National Grassland	28-Sep-1993	Vicinity south and southwest of Forest route 876 and Forest route 801 intersection	southern aspect. D: associated with the butte and its runoff and depositional processes. E: plants occur in erosion breaks associated with a clay butte ridge and occur at the edge of what appears to be an old erosion feature. Area relatively well vegetated; F: Substrate is clay with a clay/gravel surface. Colony A is found at the upper end of the bentonite slump; colony B is in a clay outwash area immediately adjacent to a wet area where willows are growing	total. 2 to 6 inches tall, reddish and cured out. Comments on sub -occurrences A: Large plants give impression of more plants than there were. Plants in the drainage and smaller than those on the level ground. Light grazing by cattle with some cattle trails. "The area is generally disturbed soils, but it is most likely natural; "B: Light grazing. Some *Salsola iberica*; C: this site was observed in a previous survey, but is currently more revegetated and may be speculated to be approaching extirpation	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)
ND 31	N/A	McKenzie	USFS Region 1 Little Missouri National Grassland	26-Jul-1995	West of county road 27 and Forest route 833 intersection., Bowline Creek oil field	1995: 5% shrub cover, 10% forb cover, 10% graminoid cover. South aspect; 1 to 2% slope, Open dry bottom, soil - clay. *Agropyron smithii/Carex filifolia* habitat. 2001: Population occurred in a shallow drainage that received runoff. *Agropyron smithii* formed dense stands in some areas. Claypans were common. Grasslands surrounding the area were principally *Stipa comata/Carex* habitat type	1995: Approximately 200 individuals: 70% in flower, 30% vegetative. 2001: Approximately 2,000 individuals	North Dakota Natural Heritage Inventory (2005)
ND 32	N/A	McKenzie	USFS Region 1 Little Missouri National Grassland	1994 25-Jul-1995	Within approximately 1 mile and southwest of Softwater Spring in vicinity of Sheep Creek	1994: Alluvial fans at base of knolls. The presence of these populations on slumped soil steps with close association of dense grasses is not typical habitat for this species. Micro-populations may exist in similar habitat types. 60% bare ground 1995: west, southwest, east aspect;	1994: " Approximately 600 individuals, 15% vegetative, 75% in flower and fruit." 1995: 200 individuals spread around base of hillock "but probably 1 population" within 800 yards. 60% in flower, 40% vegetative	North Dakota Natural Heritage Inventory (2005)

(continue next page)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 32	N/A	McKenzie	USFS Region 1 Little Missouri National Grassland	1994 25-Jul-1995	Within approximately 1 mile and southwest of Softwater Spring in vicinity of Sheep Creek	2% slope, Open dry bottom. 5% shrub cover, 10% forb cover, 10% graminoid cover, 75% bare ground		North Dakota Natural Heritage Inventory (2005)
ND 33	N/A	McKenzie	USFS Region 1 Little Missouri National Grassland	20-Aug-2001	In Modak oil field. South east of Forest Route 837 and Alkali Creek. Occurrence extends across 2 sections - approximately 3 miles from the Montana-North Dakota Stateline	Sub-occurrence A: Plants on clay pan areas and barren areas associated with a small residual butte in microdrainages. On plateau top with 0% slope. Xeric open conditions; 80% bare ground, 5% rock cover. Sub-occurrence B: On plateau top with 0% slope. Xeric open conditions; barren with 50% rock cover. The area receives runoff from clay butte. Plants growing in a slight drainage near two-track	Sub-occurrence A: Plants in scattered clusters and as isolated individuals. Estimated 800 individuals. Sub-occurrence B: 30-40 plants. Sub-occurrence A: Area grazed by domestic livestock (cattle) and some trails established especially near fenceline. A two-track dissects the population and since the area is on a level top it has been used "quite a bit" for vehicle turn around. In some area *Suaeda moquinii* has become very dense and *Eriogonum visheri* is not found in these areas. Sub-occurrence B: Area grazed by domestic livestock (cattle). Two-track received high recent use, probably due to seismic exploration in the area. No non-native species in either area	Diller (2002)
ND 34	h	McKenzie	Private land, may extend onto USFS Region 1 Little Missouri National Grassland	08-Sep-1993 2001	West of county road 3, approximately 3 miles north of its intersection with Highway 68	1993: Clay outwash community on a gentle slope below knob. Aspect 280 degrees west, clay substrate with clay/gravel surface. Colonies bounded by established grasslands and grass patches in clay outwash	1993: Approximately 27,000 individuals in population (Vanderpool 1993). Basal coverage is 25% for all vegetation, 1% for *Eriogonum visheri*. Subsite A: 8,694 individuals, Subsite B: 8,375 individuals, Subsite C: 10,206 individuals. Plants of varying ages, 3 to 8 inches in height, mostly with seeds and are curing out 2001: No *E. visheri* plants (Diller 2002)	Vandepool (1993); Diller (2002); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 35	h	McKenzie	USFS Region 1 Little Missouri National Grassland and private land	08-Sep-1993	West of county road 3, approximately 1.75 miles north of its intersection with Highway 68	Clay outwash community at base of clay butte. C Slope varies from 1 to 10%, 114 degree east southeast. *Eriogonum visheri* community is in a flat washout area at base of exposed clay slopes. Generally bounded by the base of clay slope at one side and grassland type establishment on the other. Except for site C where *E. visheri* can be found among grass types growing up the slope from the clay washout area	Entire clay washout area has a basal coverage of approximately 10 to 20% for all plant types, 1% for *Eriogonum visheri*. Individuals in obvious clusters. Approximately 24,000 individuals in population (Vanderpool 1993). Cluster A: 10,500 clustered individuals. Cluster B: 5,700 clustered individuals. Cluster C: 7,738 individuals scattered amongst upland grass types. Overall the entire washout has individuals sparsely scattered	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)
ND 36	h	McKenzie	USFS Region 1 Little Missouri National Grassland	1993 16-Au-2001 07-Sep-1993 13-Sep-1993 2001	0.9 miles north of Highway 68 on Forest Road 845. East of Forest route 838 and northeast of its intersection with Highway 68	1993: Clay outwash community, gravel/clay outwash at base of badlands formation. Aspect of 140 degrees southeast, relief is very smooth. Xeric site conditions. Clay substrate with clay and gravel on the surface. Population is bounded by clay butte slope and grassland establishment on all three subsites. Site naturally erosive (Vanderpool 1993) 2001: Site A. Plants most common on erosion features that occurred mid-slope although some plants were found near the base of the butte system. South-facing slopes. Site B. Plants occur on mid-slope area downhill from butte system. Soils are mostly barren, clay substrate with some sandy wash on the surface. Plants found growing on the flats, in microdrainages and most commonly on the edges of erosion (continue next page)	Occurrence with many sub-occurrences (subsites). 1993: Total individuals approximately 42,000. Approximately 1,050 in Subsite A with majority of plants in a few clumps with some scattered between. Subsite B has approximately 150 plants in clusters. Subsite C has approximately 40,000 individuals with the majority in three clusters and the remainder sparsely scattered. Ages vary, plants 2 to 8 inches high. Most plants have seeds and are curing. Most reddish in color 2001: Site A. Less than 1,000 individuals covering an extensive area. Site B: 671 total plants in 500x2000 ft in 11 patches of between 6 (in 2x2’) to 150 (in 5x20’). Likely in site 3 of 1993. Site C. 250 individuals. Likely to (continue next page)	

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 36	h	McKenzie	USFS Region 1 Little Missouri National Grassland	1993 16-Au-2001 07-Sep-1993 13-Sep-1993 2001	0.9 miles north of Highway 68 on Forest Road 845. East of Forest route 838 and northeast of its intersection with Highway 68	features. Limonite common in some areas. Water quality through the area appears to be saline and/or sodic. Site C. Sandy wash at base of a residual clay butte	be a different colony to those in 1993 Comments: 1993:Pipeline immediately downslope of population 2001: Site A: "Grasslands in the area were very lush and [*E. visheri*] population may be succumbing to natural plant succession in the area" (Diller 2002). Site B: *Kochia scoparia* was quite prolific in the area, and may inhibit expansion of *E. visheri* in future years	Vanderpool (1993); Diller (2002); North Dakota Natural Heritage Inventory (2005)
ND 37	h	McKenzie	USFS Region 1 Little Missouri National Grassland	05-Aug-1993 (A) 07-Sep-1993 (B,C) 10-Sep-1993 (D,E) 14-Jul-1997 19-Aug-2001	1993: Junction of Highway 68 and Forest Road 845 to 0.9 miles north of intersection. Sub-occurrence A: along western side of valley. Sub-occurrence B: on northeast of scoria road along base of small clay buttes. Sub-occurrence C: 0.75 miles from pipeline crossing. Sub-occurrence D: adjacent to ditch and approximately 100 yards around extensive badlands formation. Sub-occurrence E: overlaps with other sub-occurrences 2001: Horse Creek School location, north of Highway 68	1993: Sub occurrence A: Base of badlands. Clay outwash community at base of moderate-low relief badlands feature, relatively smooth, east-facing exposure, soil a dense compact fine-grained clay, with surface scattering of gravel. Individuals most numerous adjacent to microdrainages across the outwash pan. Sub occurrence B: Clay outwash community at base of badlands formation; aspect 132 southeast, slope 2-5%, substrate clay with clay and gravel on surface. Sub occurrence C: Along base of ridge in outwash area above riparian area. Clay outwash community, 5-7% slope from toe 3%.Sub occurrence D: Clay outwash community at base of small clay buttes. Aspect 168 south, clay substrate with clay/ gravel surface. Sub occurrence E: Bentonite plateau at the end of a low ridge with standard outwash community and another colony on (continue next page)	1993: Sub occurrence A: Total vegetative cover 25%, *Eriogonum visheri* cover 5%. An estimated 1,400 individuals. [Largest colony at base of slopes]. Scattered clumps of individuals were also found along crest of the butte. NE NE Sub occurrence B: Basal cover of total vegetation 10-15%, of *E. visheri* 1%. Approximately 1,800 individuals. SE SE Sub occurrence C: Approximately 130,000 individuals. Sub occurrence D: Basal cover of total vegetation approximately 10-20%, of *E. visheri* 1%. Approximately 30,000 individuals. Sub occurrence E: Approximately 103,000 individuals - overlaps with other sub-occurrences. 1997: May be sub-occurrence C: 70 individuals. 2001: Sub occurrence A: 130 individuals. Possibly Sub-occurrence D: (continue next page)	Vanderpool (1993); Diller (2002); North Dakota Natural Heritage Inventory (2005)

Table 2 (cont.).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 37	h	McKenzie	USFS Region 1 Little Missouri National Grassland	05-Aug-1993 (A) 07-Sep-1993 (B,C) 10-Sep-1993 (D,E) 14-Jul-1997 19-Aug-2001	1993: Junction of Highway 68 and Forest Road 845 to 0.9 miles north of intersection. Sub-occurrence A: along western side of valley. Sub-occurrence B: on northeast of scoria road along base of small clay buttes. Sub-occurrence C: 0.75 miles from pipeline crossing. Sub-occurrence D: adjacent to ditch and approximately 100 yards around extensive badlands formation. Sub-occurrence E: overlaps with other sub-occurrences 2001: Horse Creek School location, north of Highway 68	clay outwash plain 1997: May be sub occurrence C: Associated plant community - Grasses. Habitat: "ARTCAN"; Associate plant species - Shrubs. 2001: May be sub occurrence A or new colony: Plants at base of residual clay butte, in microdrainages and on erosion features associated with butte. Sub-occurrence F: between butte base and fenceline. Sub-occurrence G: Colony occurred next to small butte system, plants prolific in the sandy wash that occurred at the bottom of the butte. A few plants were in a slight drainage on the north side of the main colony and also on a small terrace on the butte	two colonies with a total of approximately 1,200 plants. No plants on the clay butte in area. Sub-occurrence F: 40 plants. Sub-occurrence G: 600 plants. 1993: Sub occurrence B: Plants senescent although no sub-freezing temperatures had occurred. Sub occurrence D: Population vigorous, and skeletons of plants from previous year indicate site produced *Eriogonum visheri* for at least 2 years. Site highly disturbed, power line, fence line and pipeline construction impacting immediate area. 2001: Possibly 1993-Sub-occurrence D: A pipeline dissected one colony and the other colony occurred in a ditch adjacent to the gate for pasture access. Sub-occurrences F, G: Vigorous grass growth and limited badland habitat	Vanderpool (1993); Diller (2002); North Dakota Natural Heritage Inventory (2005)
ND 38	h	McKenzie	USFS Region 1 Little Missouri National Grassland (may extend on to private land)	10-Sep-1993	Approximately 0.5 miles west of County road 3 and north of Highway 68	Clay outwash community below badlands formation. Aspect 22 degrees north, relief smooth, xeric site conditions, clay substrate with clay/gravel surface. Population bounded by established grasses	Approximately 220 individuals. Most [plants] 2 to 4 inches tall, mainly with seeds and curing out. Feeble/normal vigor, site in continuous erosion	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)
ND 39	h	McKenzie	North Dakota State/USFS Region 1 Little Missouri National Grassland	09-Sep-1993 14-Jul-1997	Approximately 1 miles west of County road 3 in vicinity of Highway 68	1993: Clay outwash community with clay substrate and a clay/ gravel surface. *Eriogonum visheri* found at base of clay slopes. Xeric site. Aspect 352 degrees, north, slope is 0 to 5%. Population bounded by clay slope and grassland types 1997: Associated community: (continue next page)	1993: Approximately 24,000 individuals in at least 3 subsites [colonies]; Subsite A: 16,760 individuals. In two clusters. Remainder of area has scattered individuals in sparse numbers throughout the clay washout areas. ... The number of individuals would be (continue next page)	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)

Table 2 (concluded).

State/ No.	Potential occurrence association	County	Land Management[1]	Observation dates	Location	Habitat	Abundance and Comments	Sources of information[2]
ND 39	h	McKenzie	North Dakota State/USFS Region 1 Little Missouri National Grassland	09-Sep-1993 14-Jul-1997	Approximately 1 miles west of County road 3 in vicinity of Highway 68	*Ceratoides lanata*; Habitat: *Artemisia cana*; Associated plant species: *Agropyron smithii*	approximately 1,500. Subsite B: one small group of 8 individuals on top of ridge (in small depression). Subsite C: approximately 217 individuals 1997: Population size - 24 individuals. *E. visheri* vary in size from 2 to 8 inches high with a 6 inch average. Most are cured out and reddish colored, but some are still green and flexible. Good seed production."	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)
ND 40	h	McKenzie	North Dakota State and USFS Region 1 Little Missouri National Grassland	09-Sep-1993	Approximately 1.25 miles west of County road 3 in vicinity north of Highway 68	Clay outwash community with clay substrate and clay/gravel surface. Nearly mid-slope towards wooded draw, xeric conditions. Aspect 354 degrees north. *Eriogonum visheri* population is bounded on one side by toe of clay butte slope and by grassland type establishments on either side	"Basal cover of all plant types: 10%, basal cover of *E. visheri*: <1%. Subsite A: 130 individuals in a cluster, Subsite B: 400 individuals in a cluster, Remaining outwash contains highly scattered individuals estimated at approximately 3,591. Structure of *Eriogonum visheri* population varies from 2 to 8 inches tall individuals. Most of these individuals are curing out and reddish-colored and quite brittle. The larger plants have very few among them that are yet green and flexible."	Vanderpool (1993); North Dakota Natural Heritage Inventory (2005)
ND 41	N/A	Mountrail	Likely Private	05-Aug-1970	In White Earth River Valley, less than 4 km from the East Tioga Oil and Gas Field	Outwash from Clay Butte	No information	North Dakota Natural Heritage Inventory (2005)

[1]NG - abbreviation for National Grasslands.

[2]Herbaria abbreviations:

F = Field Museum of Natural History, Chicago, Illinois

GFND = University of North Dakota Herbarium, Grand Forks, North Dakota

KANU = R.L. McGregor Herbarium, University of Kansas, Lawrence, Kansas

MONT = Montana State University, Bozeman, Montana

MONTU = University of Montana Herbarium, Montana

RM = Rocky Mountain Herbarium, University of Wyoming in Laramie, Wyoming

No specific management plans have been developed for *E. visheri* in either Region 1 or 2. A conservation strategy is being prepared for *E. visheri* in Region 1 (Washington personal communication 2005).

USFS policies also include: "Assisting states in achieving their goals for conservation of endemic species; as part of the National Environmental Policy Act process, reviewing programs and activities, through a biological evaluation, to determine their potential effect on sensitive species; avoiding or minimizing impacts to species whose viability has been identified as a concern; establishing management objectives in cooperation with the States when projects on National Forest System lands may have a significant effect on sensitive species population numbers or distributions; and establishing objectives for Federal candidate species, in cooperation with the FWS or NMFS [National Marine Fisheries Service] and the States" (Forest Service Manual 2670.3 – Policy and 2670.32 - Sensitive Species, Bosch 2004). If impacts from USFS activities and projects cannot be avoided, then the significance of potential adverse effects on the population or its habitat within the area of concern and on the species as a whole must be analyzed. The line officer with project approval authority decides whether to allow or disallow impact, but the decision must not result in loss of species viability or create a significant trend toward listing under the federal Endangered Species Act (Bosch 2004).

Most of the land occupied by *Eriogonum visheri*, including that within the National Forest System, is open to livestock grazing and resource development. Because of its status as a USFS sensitive species in Region 2, effects of projects on occurrences of *E. visheri* are analyzed and documented during land management planning on National Forest System land. For example, in 1993, a biological evaluation resulted in a request that a gravel operation on the Little Missouri National Grassland avoid the population of *E. visheri* that was near the proposed development (Lenz 1993).

National Park Service

The two occurrences within Badlands National Park are protected from most kinds of development. The National Park Service manages land primarily for its scenic or historical significance, and most parks are more oriented to recreation than either national forests or wilderness areas (Environmental Media Services 2001). Logging, mining, and other development generally allowed in national forests are usually prohibited in national parks (Environmental Media Services 2001). *Eriogonum visheri* is also specifically considered during management planning in the park for fire (U.S. National Park Service 2004), weed control (U.S. National Park Service 2003), and resource management (Dingman 2004).

Seed banking

Eriogonum visheri seed has been collected (occurrence SD 25, **Table 1**) and sent to the Center for Plant Conservation (Locklear undated). The Center for Plant Conservation is dedicated to preventing the extinction of native plants in the United States and maintains many taxa as seed, rooted cuttings, or mature plants, depending upon the taxon's requirements.

Adequacy of current laws and regulations

In North and South Dakota, *Eriogonum visheri* has no legal protection or status outside of National Forest System and National Park Service lands; in Montana, it has no protection outside of land managed by the BLM. Maintaining *E. visheri* as a USFS sensitive species and as a watch species by the Montana BLM ensures that the taxon is considered during management planning and encourages periodic evaluation of its status on National Forest System and BLM lands. The adequacy of this designation in conserving *E. visheri* will depend upon the judgments made by agency personnel during project planning.

Biology and Ecology

Classification and description

Systematics and synonymy

Eriogonum visheri is a member of the Polygonaceae, commonly called the buckwheat family. The Polygonaceae is composed of approximately 900 species in 40 genera (Reveal 1978). Members of this family are found throughout the world, but species in the genus *Eriogonum* are native only to North America (Stokes 1936, Reveal 2005b). *Eriogonum* species are widespread in North America, growing from east-central Alaska south into central Mexico and east into Florida; the majority of species, however, occur in the western United States (Stokes 1936, Reveal 1978).

Within the Polygonaceae, *Eriogonum* belongs to the subfamily Eriogonoideae. The genus *Eriogonum* is very large and includes approximately 250 species rangewide (Reveal 2005b), divided among eight subgenera. These subgenera are divided into sections, which in turn are divided into subsections. Each finer subdivision denotes increasing relatedness among species within the same subdivision. *Eriogonum visheri* is the type and one of only two species in the subsection *Lathetica*, in the section *Gomphotheca* of the subgenus *Ganysma* (Reveal 1969). *Eriogonum aliquantum*, the other species in subsection *Lathetica*, is also rare and is restricted to clay soils in northern New Mexico (Reveal 1976). The affinity between the two is clear, and the two are morphologically very similar (Reveal 1976). *Eriogonum aliquantum* has a distinctly different flavonoid profile from *E. visheri*, as determined by two-dimensional thin-layer chromatography, and it morphologically differs from *E. visheri* by having glabrous flowers, shorter achenes, and narrower leaves (Reveal 1976). Authors of taxonomic treatments in the recent Flora of North America have been requested to place taxa that they consider most closely related in immediate sequence in the text (Spellenberg personal communication 2006). Therefore, by sequence of presentation, Reveal (2005b) considers *E. visheri*, *E. aliquantum*, and *E. gordonii*, all in the subgenus *Ganysma*, to be closely related.

Taxonomic affinities of *Eriogonum visheri* have been the subject of some speculation. Over (1932) indicated that *E. visheri* was synonymous with *E. gordonii*. *Eriogonum gordonii* occurs in certain parts of Arizona, Colorado, Nebraska, Utah, Wyoming, New Mexico, as well as southwestern South Dakota (Reveal 2005b). Stokes (1936) noted that *E. visheri* displays some characteristics that fall midway between *E. mohavense* and *E. reniforme* ssp. *pusillum*[2].

Stokes (1936) studied the genus *Eriogonum* and sought to clarify species distribution and relationships. She placed *Eriogonum* species into four numbered sections using a combination of geology, geography, and growth habitat. Stokes (1936) placed *E. visheri* in Section 2, in which she included species that during their evolutionary process lost their perennial habit and acquired varying degrees of pubescence after being exposed to aridity and short rainy seasons. Species in Section 2 were characterized by their rapid growth and establishment, which permits survival in unstable and harsh conditions.

History of species

Eriogonum visheri was apparently first collected in North Dakota by W.B. Bell (#233 F) in 1907 from Wade, near the Cannonball River (**Table 2**). Although not described until 1913, *E. visheri* was recognized as being a unique species by most early botanists. Aven Nelson wrote in his notes that *E. visheri* was "As far as I can see now a good species; will describe it soon" (Visher 1912). Nelson (1913) went on to describe the taxon using the material collected by Stephen S. Visher (#536 RM) from Meadow in Perkins County, South Dakota (**Table 1**). *Eriogonum visheri* was named in honor of Stephen S. Visher; since that time, its uniqueness as a species has not been in doubt (Reveal 1978).

The similarity of *Eriogonum visheri* to other taxa may have led to some cases of misidentification. For example, the Great Plains Flora Association (1986) noted that *E. visheri* might have been mistaken for *E. trichopes* in a report by Stevens (1963). These species are not sympatric, *E. trichopes* being common in the arid regions of the southwestern United States into northern Mexico (Reveal 2005b). Van Bruggen's description of *E. visheri* in the 1976 edition of the Flora of South Dakota suggests that specimens of *E. gordonii* were included in his concept of the taxon (Van Bruggen 1976). *Eriogonum visheri* and *E. gordonii* were included as separate species in the 1985 edition (Van Bruggen 1985).

Common names for *Eriogonum visheri* include Visher's buckwheat, Visher's wild buckwheat, Dakota eriogonum, Dakota buckwheat, and Visher's eriogonum. The USFS currently uses the common name "Wisher's buckwheat"; this is based on an erroneous common name published by USDA Natural Resources Conservation Service (2005) on their PLANTS website. The error is apparently being corrected (Guala personal communication 2006), and the common name Visher's buckwheat is used here.

Non-technical description

The following description is based on Ode (1987) and Reveal (2003, 2005b). *Eriogonum visheri* is a small, erect, summer annual plant (**Figure 1**, **Figure 2**). Plants typically vary from 10 to 35 cm tall and, depending upon conditions, some may be up to 40 cm tall. The plants are generally only sparsely hairy. The stems are usually solitary from the root crown with two or three branches at the first node. This di- or trichotomously branching pattern continues several times, with the branches becoming thinner in diameter. The leaves form a rosette at the base of the stem, and there is a whorl of a few, smaller leaves at the first node. The basal leaf blades are rather thick and mostly broadly oval in shape,

[2]Currently accepted as *E. pusillum* (Reveal 2005b).

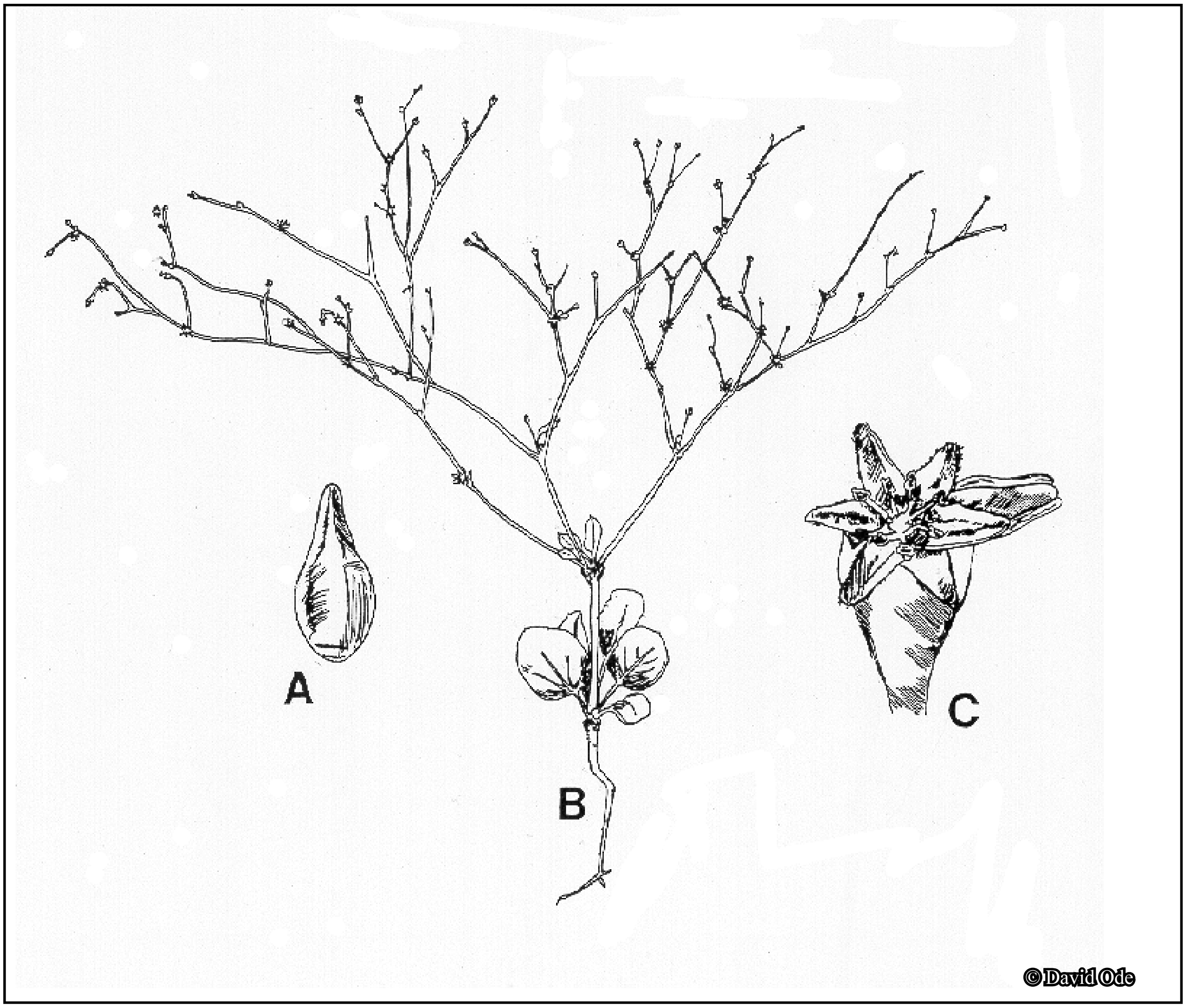

Figure 1. Illustration of *Eriogonum visheri*. Illustration by Larry Albers, from Ode (1988), used with permission from the South Dakota Game, Fish, and Parks Department. A scale was not provided with the original illustration. As a guide to size, A) the achene is up to 3 mm long, B) the basal leaf blades are up to 2 cm long and the plant up to 35 cm tall, C) the flower is up to 2.5 mm long.

15 to 20 mm long, and on petioles that can be longer or shorter than the blade. The leaf blade is mostly smooth, green, and hairless although hairs occur at the margins, along the midvein and on the petioles (leaf stalks). The involucre is a minute cup-like structure that subtends a small cluster of flowers. It is top-shaped (inversely conical), hairless, from 0.8 to 1.5 mm long, and it has five teeth, each 0.3 to 0.8 mm long. The flowers are yellowish and inconspicuous (see inset in **Figure 2**). They are 1.2 to 2.5 mm long with exserted stamens that are approximately 1.2 to 2 mm long. The fruits are shiny dark brown, smooth, achenes and only approximately 2 to 3 mm long (**Figure 3**).

Four other annual species of *Eriogonum* can be found within the range of *E. visheri*: *E. cernuum*, *E. annuum*, *E. salsuginosum* and *E. gordonii*. It is unlikely that the first three species would be mistaken for *E. visheri*, especially during flowering. *Eriogonum cernuum* and *E. annuum* have densely hairy foliage (Reveal 2005b). In addition, *E. cernuum* has strongly reflexed involucral peduncles, and *E. annuum* has stem leaves rather than a distinct basal rosette (Vanderhorst et al. 1998). *Eriogonum salsuginosum* has a deeply lobed, cup-shaped involucre, while that of *E. visheri* is shallowly lobed and top-shaped (Ode 1987). Unlike *E. visheri*, *E. salsuginosum* looks somewhat succulent, being bright green. *Eriogonum gordonii* is the most likely of the four sympatric species to be mistaken for *E. visheri*. *Eriogonum gordonii* has white, hairless flowers rather than yellow, slightly hairy flowers. In addition, all of the involucres of *E. gordonii* have stalks while most

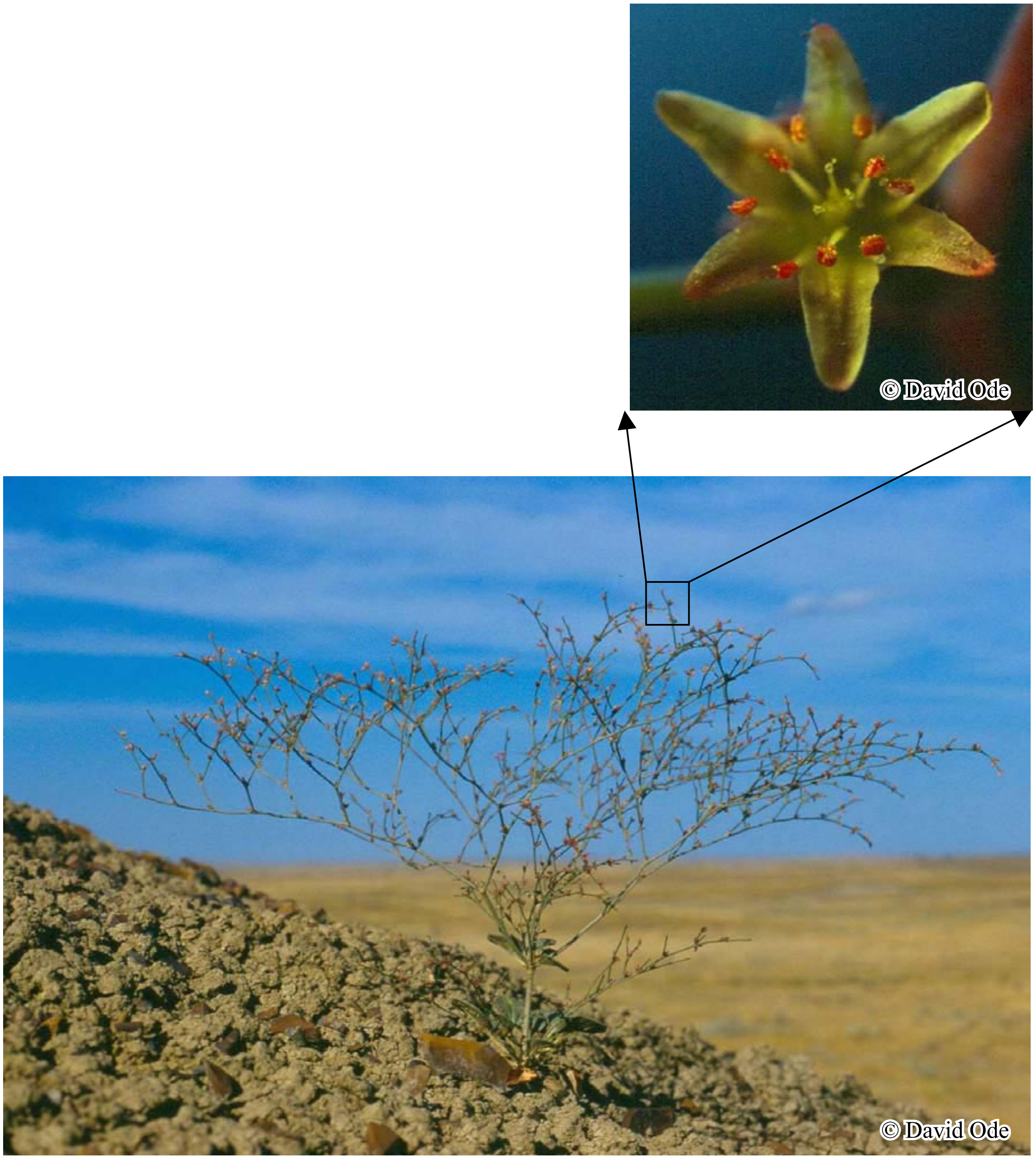

Figure 2. Photograph of *Eriogonum visheri*. The inset shows a close-up photograph of the flower. Courtesy of David Ode, South Dakota Game, Fish, and Parks Department, used with permission.

of the involucres of *E. visheri* are stalkless or sessile (Ode 1987). In South Dakota, *E. gordonii* occurs in similar habitats as *E. visheri* (Ode 1987).

There are other opportunities for misidentification. Early in the season when plants are seedlings, several annual species may be confused with *Eriogonum visheri*, especially by searchers unfamiliar with all stages of its life cycle (**Figure 3**). *Polygonum ramosissimum*, which exhibits considerable morphological variation, presents another opportunity for casual misidentification (Ode 1987). At a distance, *P. ramosissimum* has a similar profile to *E. visheri* and commonly occurs in the same habitats (Ode 1987). Although branches can occur along the length of the *P. ramosissimum* stem, they are often concentrated

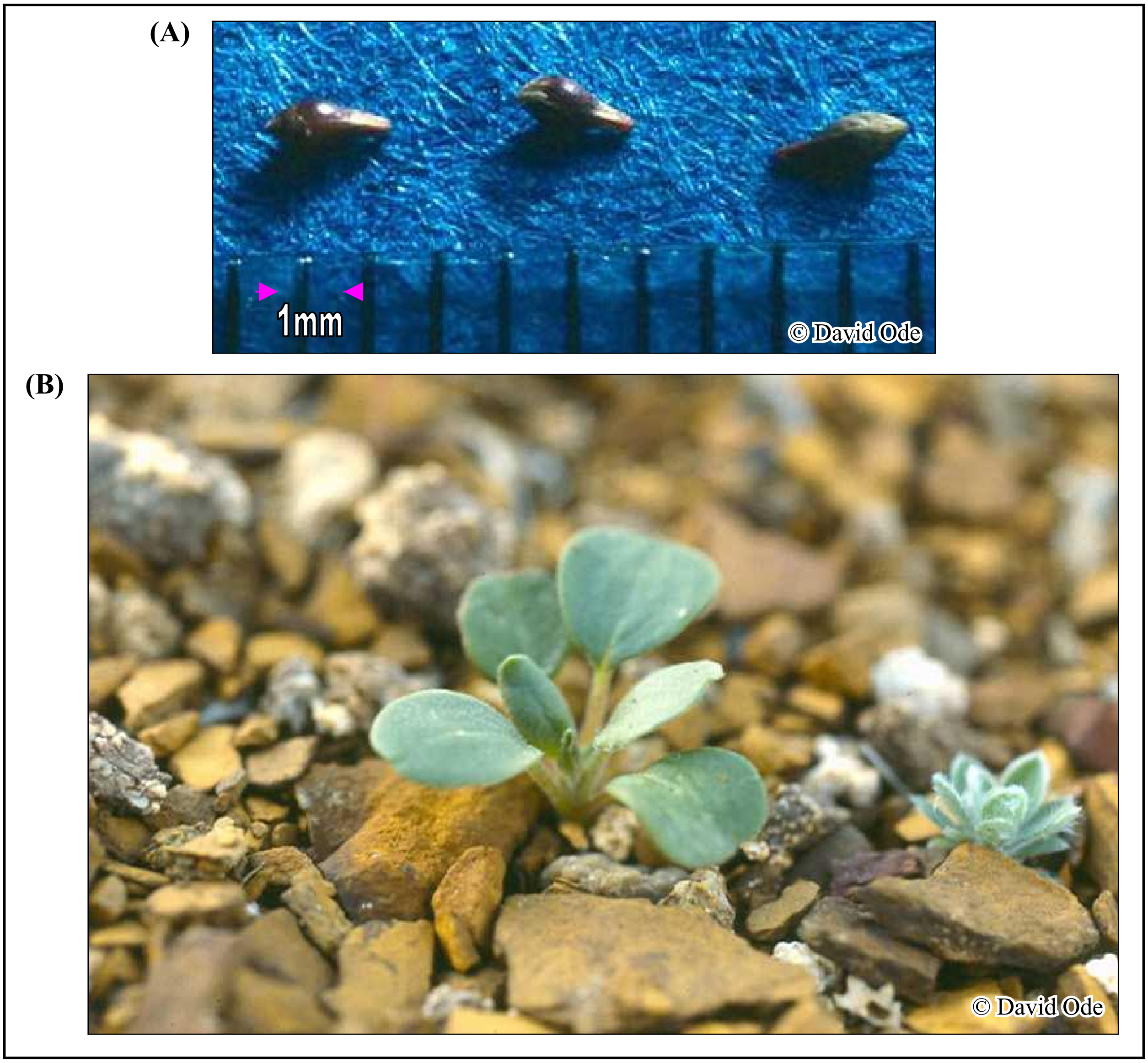

Figure 3. Photographs of *Eriogonum visheri* (A) achenes and (B) seedling. Courtesy of David Ode, South Dakota Game, Fish, and Parks Department, used with permission.

in the upper half (Van Bruggen 1976, Costea et al. 2005). Differences between the two taxa can be seen more clearly when observed at close range. Leaves of *P. ramosissimum* alternate along the stem, and its small flowers are enclosed by the stipules in the upper axils (Van Bruggen 1976, 1985, Costea et al. 2005). *Polygonum ramosissimum* plants tend to be larger than *E. visheri*, ranging from 10 to 100 cm or even 200 cm tall (Van Bruggen 1976, Costea et al. 2005).

References to technical descriptions, photographs, line drawings

Technical descriptions of *Eriogonum visheri* are in Nelson (1913), Reveal (1969, 2005b), and Great Plains Flora Association (1986). A description, photograph, and line drawing appear in Ode (1987). A description with a photograph of the plant and its habitat is available on the Internet by Locklear (undated), and the Montana Natural Heritage Program (1997-2005). An illustration of the plant and a description is also available on the USGS Northern Prairie Wildlife Research Center website. The **References** section has the Internet addresses of these sites.

Distribution and abundance

The key elements of the distribution and abundance of *Eriogonum visheri* include limited geographic distribution, restricted habitat, complex habitat requirements that are not well understood, highly variable temporal and spatial abundance, and highly variable individual plant density.

The range of *Eriogonum visheri* is restricted to the eastern parts of the Unglaciated Missouri Plateau. This region of the Great Plains lies just beyond the limits of the continental glaciers during the Pleistocene Epoch (Trimble 1980). The Unglaciated Missouri Plateau displays the greatest variety of landforms found anywhere in the Great Plains (Trimble 1980). Within the Missouri Plateau, *E. visheri* is endemic to the badlands of western South Dakota, southeastern Montana, and southwestern North Dakota (**Figure 4**; Ode 1988, Vanderhorst et al 1998).

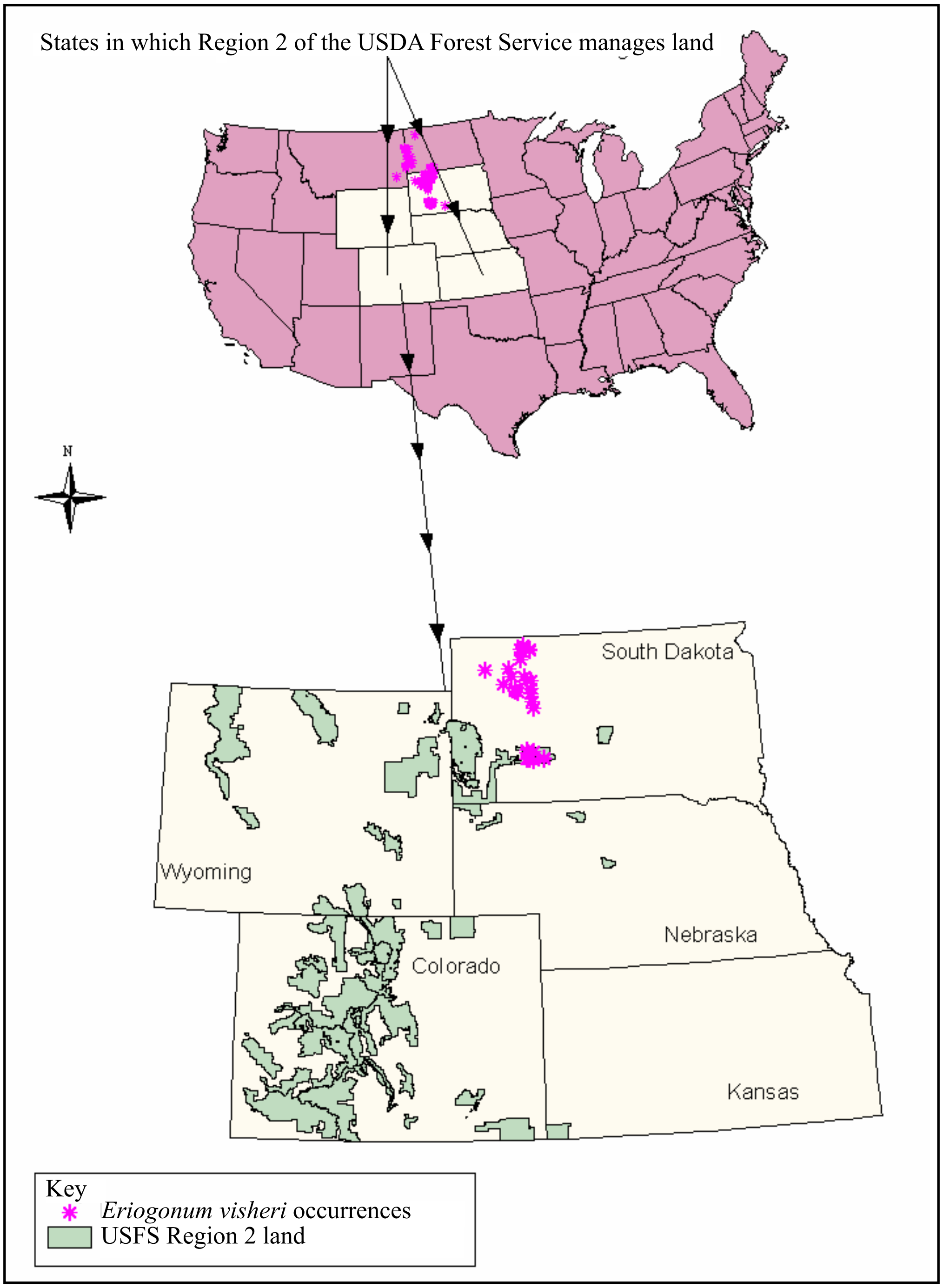

Figure 4. Distribution of *Eriogonum visheri* occurrences.

Eriogonum visheri has been reported from Corson, Harding, Jackson, Pennington, Perkins, Meade, Mellette, and Ziebach counties in South Dakota (**Table 1**) and Billings, Golden Valley, Grant, McKenzie, Mountrail, Sioux, and Slope counties in North Dakota (**Table 2**). Only one occurrence has been documented in Montana, in Carter County (**Table 2**).

Although *Eriogonum visheri* can be locally common south of the Williston Basin boundaries in south-central South Dakota, it appears to be most abundant in the southern end of the Williston Basin in western North Dakota and at the edge of northwestern South Dakota (**Table 2**). The sedimentary rocks of the Williston Basin consist of sandstones, shale, limestone, and dolomites, and they range in age from early Cambrian through late Quaternary (Vaculik 2001). The Williston Basin extends north into south-central Canada (Vaculik 2001), but climatic conditions, as well as changes in edaphic conditions, are likely the primary factors that prevent expansion of *E. visheri* throughout the Williston Basin.

Approximately 77 *Eriogonum visheri* occurrences were found in South Dakota between 1912 and 2001. Of these, 22 are on the Buffalo Gap National Grassland, which is managed by Region 2 (**Table 1**). As is the case throughout the range of *E. visheri*, the size of individual occurrences within Region 2 is highly variable. Estimated abundance within an occurrence ranges from fewer than 50 individuals to more than 10,000 individuals (**Table 1**). It is possible that the difference in size reflects to some extent the area surveyed. A report of a small number of plants may represent a colony within a much larger occurrence that was not searched. However, this cannot be assumed without investigation because the existence of small isolated patches of *E. visheri* has been confirmed.

Eriogonum visheri is apparently restricted to specific clay and sandy-clay substrates. It can be locally common within its restricted habitat although occurrence size varies both spatially (from location to location) and temporally (from year to year). Within any given year, occurrence characteristics vary considerably, not only in number of individuals but also in their density (**Table 1**, **Table 2**). Sites may cover 1,000 acres, but the area occupied by plants is typically less than 1 percent of the site (**Table 1**, **Table 2**; Ode 1987, Schmoller 1993). In 1993, approximately 961 acres of suitable habitat were surveyed on the Buffalo Gap National Grassland, but the area occupied by *E. visheri* was estimated to be only 4.84 acres (0.5 percent; Schmoller 1993). Individual plants appear to have a spatially aggregated or patchy distribution even within suitable habitat. This patchiness cannot be simply ascribed to geology or habitat conditions (Washington personal communication 2005). However, suitable habitat has not been systematically defined; it may be described only as habitat that, from casual observation, appears suitable for the species but is not occupied by it. More study is needed to determine the amount of land that represents true potential habitat for *E. visheri*.

Occurrence versus population terminology

An occurrence of *Eriogonum visheri* is somewhat difficult to define because plants are often scattered as clusters or as isolated individuals over the landscape with relatively little of the apparently suitable habitat being occupied. An additional challenge to defining an occurrence is that the taxon is an annual, and the longevity of a particular colony is not known. Seed dispersal may be an important factor in determining where an occurrence will exist in years subsequent to an initial observation. A simple scenario could be imagined where an occurrence at the top of a butte that appears to be extirpated several years after the initial observation could actually be represented by an occurrence that appears at the bottom of the butte. Depending upon the longevity of the seed bank, the genetic information in the original occurrence could be exhibited in an occurrence quite distant from the original one and many years after it was originally observed.

The meaning of the terms "population" and "occurrence" in **Table 1** and **Table 2** of this report also warrants discussion. Some surveyors refer to an occurrence as a population while others refer only to occurrences. In both cases, one population or one occurrence of *Eriogonum visheri* often consists of several sub-populations or sub-occurrences (Ode 1987, Schmoller 1993, Diller 2002).

A population has been defined as "a group of individuals of the same species living in the same area at the same time and sharing a common gene pool or a group of potentially interbreeding organisms in a geographic area" (National Oceanic and Atmospheric Administration 2004). In this case, the definition dictates that interaction, through pollination or seed dispersal, is likely between subpopulations or sub-occurrences. A less restrictive definition of a population is "a group of individuals of the same species that occurs in a given area" (Guralnik 1982). This definition is what the term occurrence usually implies. Where the species' genetics and its genetic dispersal distances and patterns are unknown, as is the case for *Eriogonum* *visheri*, this latter definition must be presumed when the term population is used.

Accuracy in estimating the number and size of occurrences is very important because these parameters are often used as the basis for ranking a taxon's vulnerability and for designing an appropriate conservation strategy (NatureServe 2005). In contrast to a perennial species, the number of extant occurrences of an annual species is likely to be much more variable over time. Focusing on each individual occupied patch as being one occurrence may lead to an overestimation of their number due to this variability. A better estimate can be made from considering multiple (sub)occurrences within an area where there appears to be large amounts of unoccupied habitat. NatureServe (2004) encourages the development of taxon-specific specifications to delineate an occurrence. However, in the absence of specifications, they suggest combining patches of plants that: (1) grow within 1 km of each other, or (2) grow within 3 km of each other if there are no stretches of persistently unsuitable habitat broader that 1 km between them (NatureServe 2004). These guidelines circumvent the problems associated with the spatially and temporally variable incidence of an annual taxon such as *Eriogonum visheri*. One objection to combining small colonies of the same species in relatively large areas into the same occurrence might be that there could be a tendency to underestimate their robustness against stochasticity. In some cases that may be true, but temporal variability in abundance suggests that it is just as easy to underestimate their vulnerability. In addition, all colonies in even relatively large areas are likely to be affected to a similar extent by biological or even physical events. For example, insect infestations and flash floods have widespread effects.

In this report, the guidelines outlined by NatureServe (2004) have been followed as far as possible when describing an occurrence (**Table 1**, **Table 2**). One occurrence usually consists of several sub-occurrences, which in turn are often fragmented into several colonies or even scattered individuals. Essentially, the term "occurrence" has been used to describe all plants in areas of land where there are contiguous stretches of apparently suitable habitat and it has been assumed that sub-occurrences may occur throughout the area depending upon the conditions and the year. This assumption needs to be confirmed. However, because occurrence descriptions closely match the original surveyors' reports, the terms "population" and "occurrence" are both included in **Table 1** and **Table 2**. In addition, some surveyors referred to sub-occurrences as "sites" or "subsites" (e.g., SD - 28, 29, and 48 in **Table 1**). These terms have been left in the occurrence description column of the **Table 1** and **Table 2**. It is important to note that "occurrence" as defined in this report, and "population" as used in **Table 1** and **Table 2**, do not necessarily comprise a single interbreeding group of plants; the possible genetic relationships among colonies has not been considered because gene flow, either by pollen dispersion or seed dispersal, is unknown. It is possible that in years when *Eriogonum visheri* plants are very abundant, gene flow between isolated occurrences is accelerated over "average annual rates" since the gaps between occurrences are reduced; this hypothesis needs to be carefully tested.

Despite careful examination of occurrence distribution plotted on geological and topographical maps, in some cases, occurrences reported in **Table 1** and **Table 2** may be more accurately described as sub-occurrences. In other cases, a colony designated a sub-occurrence in **Table 1** or **Table 2** may be quite isolated and more accurately described as a separate occurrence. One consideration is that occurrences at the edges of some areas may appear contiguous, but are isolated by drainages or other formations that are not apparent on the maps. In many instances, there is insufficient information associated with the report to make an accurate delineation of the occurrence.

Letters in the column marked "Occurrence association" in **Table 1** and **Table 2** indicate that occurrences with the same letter are potentially sub-occurrences within a larger area. For example, Ode (1987) suggested that the occurrence at the abandoned Keller Mine (SD - 26 in **Table 1**) is actually likely to be a sub-occurrence of the Cottonwood Creek badlands (SD - 25 in **Table 1**). The few scattered plants at this mine site were downstream from SD - 25, which is reported to be one of the largest populations of *Eriogonum visheri* known (Ode 1987). It is possible that many occurrences might actually make up a very large metapopulation. For example, the occurrences marked "h" (SD - 55 through 64 in **Table 1**) extend over approximately 13 square miles, but scattered plants were found within 1 to 3 km of each other throughout the area between 1986 and 1996. There is no information to suggest that the occurrences marked N/A in the "Occurrence association" column (**Table 1**, **Table 2**) are anything other than isolated from each other. A final factor confounding estimates of abundance and distribution is that private inholdings, especially within the Dakota Prairie Grasslands, and imprecise location descriptions have led to some uncertainty with respect to the land management authorities reported in **Table 1** and **Table 2**. This is especially the case for ND - 2, 3, 34, 41, and SD - 35 through 38.

Population trend

The key elements of estimating population trends of *Eriogonum visheri* include few historical records with which to compare information gathered within the last two decades, highly variable temporal abundance, and no systematic monitoring studies to determine population dynamics.

The majority of *Eriogonum visheri* occurrences have been discovered only since the early 1980's (**Table 1**, **Table 2**). Based on observations made periodically at the same sites over two or more years and considering the frequency with which occurrences are observed, the abundance of *E. visheri* over its range appears to have been relatively stable over the last two decades (Ode 1987, Linabery 1991, Lenz 1993, Schmoller 1993, Diller 2002, Washington personal communication 2005).

There are few records to indicate the historical abundance and distribution of *Eriogonum visheri*. Since *E. visheri* was first collected in 1907, reports and collections were infrequent until the USFWS considered it for listing under the Endangered Species Act in the 1980's. It is possible that some historical *E. visheri* populations have been reduced in size or even extirpated. For example, Ode (1987) reported that, "no colonies were located at this site although potential habitat is present" at the site located 13 miles west of Isabel where *E. visheri* was collected in 1924 (SD - 22 in **Table 1**). The area around Meadow (SD - 23 in **Table 1**) from which the type specimen was collected in 1912 is now mostly cropland and the occurrence from which the type was collected is likely extirpated (Ode 1987). Despite repeated visits in the 1980's, no *E. visheri* colonies were found in the vicinity of Cedar Pass (SD - 72 in **Table 1**) where Over made his collection in 1913 (Ode 1987). Although several precisely located colonies in the general vicinity of the Shadehill Recreation Area have been found, no colonies based on Stephens' 1971 directions (SD - 37 in **Table 1**) have been located (Ode 1987). The impact of these local extirpations on the taxon in total is unknown.

Eriogonum visheri population trends over even the last 20 years are difficult to assess. Environmental conditions, such as the amount of precipitation and temperature, are likely to affect all stages in its life cycle, from seed germination and seedling establishment to longevity and fecundity. Therefore, environmental conditions likely contribute to the variability in occurrence size that *E. visheri* exhibits over time. The reasons for the spatial variability in population size are also unknown although the size of the original population, seed dispersal patterns, and local microhabitat conditions are all possible contributing factors. The role of management practices in contributing to *E. visheri*'s variable population size both temporally and spatially have not been studied, but they may also be significant.

While there have been no systematic monitoring studies for *Eriogonum visheri*, there have been several surveys over the last two decades, especially on National Forest System land (**Table 1**, **Table 2**). Reports describing these surveys are unclear if found occurrences are new or whether they represent sub-occurrences of a previously known occurrence in the same area (**Table 1**, **Table 2**; Schmoller 1993, Diller 2002). Because of the high likelihood that there are frequent local extirpations and colonizations (one example of this might be ND - 34 in **Table 2**), it is not easy to determine long-term net gains or losses without detailed monitoring and extensive surveys. Even after monitoring programs are established, short-term trends in population size are likely to be very difficult to evaluate because of natural year-to-year variation. The absence of individuals over two or more consecutive years may not be significant. It is also possible that the occurrences are so spatially dynamic that monitoring specific occurrences without additional inventory may not reflect the overall status of the taxon and lead to overestimates of its vulnerability.

Currently, there is insufficient information to know how to interpret the absence of *Eriogonum visheri* individuals in suitable habitat and how likely it is that they may be found in a subsequent year. For example, surveys of the Buffalo Gap National Grassland in 1991 and 1993 (Linabery 1991, Schmoller 1993) failed to find plants at five sites in 1993, while numbers were greatly reduced at four other sites where plants were observed in 1991 (Schmoller 1993). At the same time, several new sites were located in 1993, and the total number of plants observed increased between the two years. The significance of the absence of plants at some sites and the overall increases in the numbers of individuals are very difficult to evaluate because the areas surveyed were larger and the intensity with which the areas were surveyed was higher in 1993 than in 1991 (Schmoller 1993). In addition, differences in environmental conditions may have influenced the survey results.

In 2004 and 2005, a floristic survey was made of the Buffalo Gap National Grassland (Sargent personal communication 2005, Kostel personal communication 2006). *Eriogonum visheri* was uncommon during this survey and was always found in relatively small occurrences, ranging from 20 to 50 plants in size (Kostel personal communication 2006). Even though *E. visheri* was rare, the plants were robust and apparently reproductive at each site where they were encountered. The few plants observed in 2004/2005 were in sharp contrast to the observations of the same surveyor in 2002, when patches of 100 or more individuals were typical and the species appeared to be very common (Kostel personal communication 2006). The surveyor speculated that the few plants observed in 2004/2005 might be due to drought in previous years (Kostel personal communication 2006).

Habitat

Eriogonum visheri habitat can be summarized as gentle, rolling plains and hillocks of barren or semi-barren loamy, sandy clay, or clay soils derived from shale in dry steppe communities that experience a semiarid continental climate.

Eriogonum visheri occurs in the badlands contained within the Great Plains-Palouse Dry Steppe province (Bailey 1976, McNab and Avers 1994). This region is characterized by rolling plains and tablelands in a broad belt that slopes gradually eastward from an elevation of 5,500 ft. (1,520 m) near the foot of the Rocky Mountains to less than 2,500 ft. (760 m) in the Central States (Bailey 1995). The badlands break the continuity of the plains; in these areas, the vegetation is a mosaic of grassland, shrubland, and areas of bare ground. *Eriogonum visheri* grows in the least vegetated parts of the mosaic, at elevations between 1,886 and 2,707 ft. (575 and 825 m) in mixed grassland and saltbush communities (**Table 1**, **Table 2**; Reveal 2005b).

Climate

Climatic conditions vary across the range of *Eriogonum visheri*. The mean annual precipitation is approximately 14 to 17 inches (36 to 43 cm) with 110 to 140 mean annual frost-free days, depending primarily on latitude. The mean temperature in January is between a minimum of 1 to 9 °F (-16 to –12 °C) and a maximum of approximately 24 to 35 °F (-4 to 2 °C) (Bryce et al. 1998). The mean temperature in July is between approximately a minimum 56 to 60 °F (14 to 16 °C) and a maximum of approximately 85 to 91 °F (30 to 33 °C) (Bryce et al. 1998). Snowfall is relatively light, but low temperatures keep the snow from melting, and strong winter winds can cause enormous snowdrifts. Most of the precipitation falls during the growing season. Thunderstorms are likely to account for a considerable amount of warm season precipitation. In the badlands, sediment runoff from rainfall on disturbed slopes may be substantial during intensive downpours.

Topography and soils

Eriogonum visheri plants grow most commonly in areas of low relief (Lenz 1995). They are frequently found at the base of buttes on slopes of less than 8.5 degrees (15 percent) and on the flat butte tops, but they have also been found at all positions on slopes of inclinations up to 35 degrees (SD - 58 in **Table 1**). Therefore, occurrences cannot be considered to be restricted to relatively flat areas (Diller 2002). Plants are frequently observed along microdrainages and outwash areas. No particular aspect appears to be favored, and plants are always reported from "open areas." The plants grow in loamy, sandy clay, and clay soils derived from shale parent material. Shale is a fine-grained argillaceous sedimentary rock formed by the compaction of clay, silt, or mud; it is defined as a sticky, fine-grained sediment (Bates and Jackson 1984, Abrahams and Parsons 1994). The term shale is often used in the generic sense and is not always used precisely (Abrahams and Parsons 1994). This being the case, a landscape described as shale can have a variety of different chemical and structural compositions. For example, there may be a wide range in the levels of iron oxides and calcite, degrees of induration and lamination, and particle size range (Abrahams and Parsons 1994). Carbonates are locally abundant in some regions of the range of *E. visheri*, but they are laterally discontinuous (Evans and Welzenbach 2000). This leads to generally alkaline but variable soil pH values. Although collectively referred to as "the badlands," these areas are geologically and chemically heterogeneous and complex (Trimble 1980). *Eriogonum visheri* has been reported to grow on members of the Pierre Shale, Fox Hills, Hell Creek, and Sentinel Butte formations, and the Chadron and Brule members of the White River formation (**Table 1**, **Table 2**, **Figure 5**; Ode 1987). These subdivisions are characterized by lithologic associations with different structural and mineral composition. Considering the time period over which they were formed, the variation may not be surprising. The Pierre Shale, Fox Hills, and Hell Creek formations originated in the Cretaceous Period, between approximately 74 and 95 million years ago. The processes forming the Sentinel Butte subdivision in the Paleocene Epoch ended approximately 60 million years ago, those of the Chadron subdivision in the Eocene Epoch ended

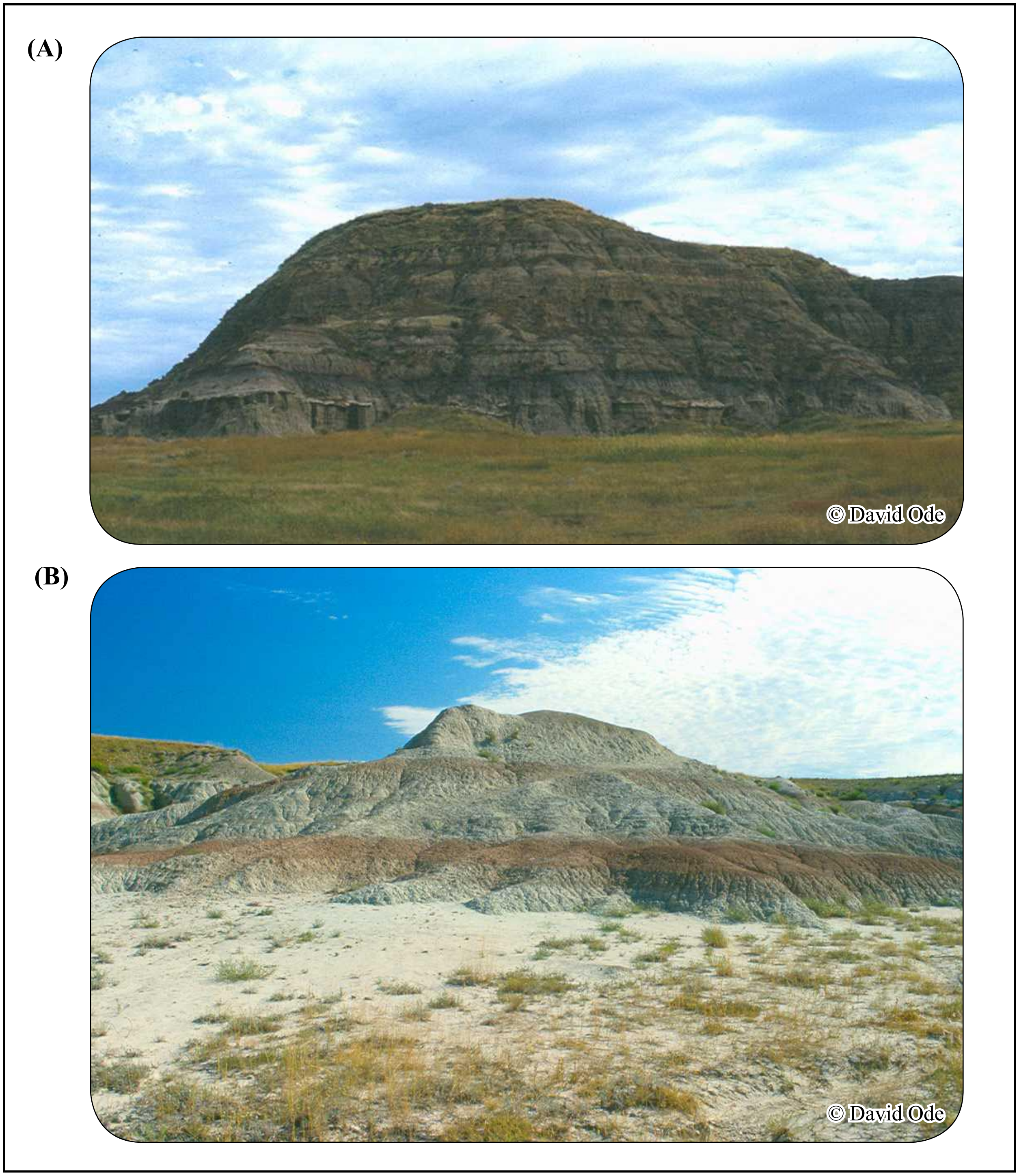

Figure 5. Photograph of E*riogonum visheri* habitats: A) Hell Creek formation and B) Chadron formation of the White River Group. Courtesy of David Ode, South Dakota Game, Fish, and Parks Department, used with permission.

approximately 33.7 million years ago while those in the Brule subdivision in the Oligocene Epoch ended approximately 23 million years ago (Trimble 1980). This variation in the geological time of deposition is also of intense interest to paleontologists because of the diversity and abundance of fossils that these rocks yield (Perisho and Visher 1912, Lanham 1991, USDA Forest Service 2001a, Hoganson and Hartman 2003).

The majority of *Eriogonum visheri* occurrences have been found in soils derived from the Hell Creek formation (**Table 1**, **Table 2**) and the Chadron and Brule members of the White River formation (**Table 1**). The Hell Creek formation consists of poorly cemented fine-grained sandstone, siltstone, carbonaceous-rich shale, mudstone, and rare lignite beds. Lenz (1995) suggested that *E. visheri* might show a particular association with the upper members of the Hell Creek formation that contain bentonite (modified volcanic ash) and bentonitic shales (Frye 1969). Further studies are needed to confirm this hypothesis. The Chadron formation is made up primarily of sandy clay that includes deposits of gravel or conglomerate several feet thick, carbonate deposits, and often coarser, sandy material (Perisho and Visher 1912, Evan and Welzenbach 2000). The Brule formation is similar, but carbonate deposits are sharply reduced (Evan and Welzenbach 2000). The clay soil surfaces have been reported to differ somewhat between the Chadron and Brule formations, possibly affecting the germination and ecology of *E. visheri*. The exposed clay of Chadron beds dries so that the "surface is loose with a gradual increase in compactness for a few inches within. As a result, cattle or men can obtain sure footing and can and do clamber about surprisingly steep slopes with safety. The clay of the Brule beds, although it sometimes is loose at the surface, is always hard at a shallow depth and footing cannot be obtained" (Perisho and Visher 1912).

Community ecology

Eriogonum visheri habitat is typically described as barren or semi-barren; up to 90 percent of the soil surface may be exposed. However, many other vascular plant species grow in areas where *E. visheri* has been found (**Table 3**). Most were found to a greater or lesser extent at each of the occurrences in **Table 1** and **Table 2**. Basal vascular plant cover is typically less than 20 percent, and basal *E. visheri* cover is rarely higher than 1 percent. Aerial vascular plant cover is less than 50 percent (Ode 1987). The *E. pauciflorum-Gutierrezia sarothrae* (fewflower buckwheat-snakeweed) shrubland association was defined during The Badlands National Park vegetation mapping project (USGS - NPS Vegetation Mapping Program 1997). This appears to be a common community type in which to find *E. visheri* (**Table 1**).

Eriogonum visheri apparently tolerates saline conditions, as demonstrated by many of its associated species such as *Iva axillaris* (poverty weed), *Sarcobatus vermiculatus* (greasewood), *Suaeda moquinii* (Mohave seablite) and *Atriplex confertifolia* (shadscale saltbush) (**Table 3**). Some species reported with *E. visheri*, such as *I. axillaris* and *Puccinellia nuttalliana* (Nuttall's alkaligrass), suggest that *E. visheri* plants enjoy locally more moist areas than the surroundings; this is consistent with its colonization of micro-drainages, butte bases, and outwash areas. *Fraxinus pennsylvanica* (green ash), *Ulmus americanus* (American elm), *Salix* spp. (reported as willows), and several grass species (e.g., *Poa pratensis* [Kentucky bluegrass]) were noted as being near *E. visheri* plants at several occurrences. The shrubs are in drainage communities while the grass communities are in swales. These species are unlikely to be directly associated with *E. visheri*, but they emphasize the mosaic nature of the vegetation and multifaceted ecological processes operating within the badlands ecosystem.

Eriogonum visheri plants grow to different sizes and in different densities, apparently depending upon the substrate and growing conditions. However, the precise conditions that affect their development are not known. In general, plants appear more vigorous and robust when growing on well-developed soils with lower pH and higher organic matter content (Ode 1987, Schmoller 1993, 1995, Montana Natural Heritage Program 1997-2004, Vanderhorst et al. (1998). Vanderhorst et al. (1998) also suggested that high plant density reflects favorable (cool and wet) conditions during the growing season.

Reproductive biology and autecology

Eriogonum visheri is a summer annual species. Flowers are produced from late June into mid to late September (Ode 1987). Seeds ripen and disperse during the summer and fall. *Eriogonum visheri* reproduces only by seed; it does not spread vegetatively. Therefore, each individual is a genetically distinct unit (genet), and although Lenz (2003) referred to ramets, *E. visheri* individuals are never ramets. Individuals naturally end their life cycle when the first freezing temperatures occur, but they can also die at any time during the growing season, frequently due to drought (Ode 1987). After death, the "skeleton" of the plants can remain standing for at least two years (South Dakota Natural Heritage Program 2005).

Little information is available on the reproductive biology of *Eriogonum visheri*. This being the case, I have had to link what is known about *E. visheri* with information derived from studies of other species. It is important to note that the relevance of the observations and research on other species to *E. visheri* needs to be established by rigorous study. In particular, more research into the pollination and reproductive biology of *E. visheri* is needed to confirm the information presented in this assessment.

Table 3. Vascular plant species associated with *Eriogonum visheri*. This is not a comprehensive list of associated species but was generated from occurrence records (South Dakota Natural Heritage Program 2005, North Dakota Natural Inventory 2005, Montana Natural Heritage Program 2005), herbarium specimens (see **Table 1** and **Table 2**) and the literature (see text).

Life form: Shrub and sub-shrub	
State	**Species**
ND, SD	*Artemisia cana*
ND, SD	*Artemisia frigida*
SD	*Artemisia longifolia*
ND	*Artemisia* sp.
MT, ND	*Artemisia tridentata*
ND, SD	*Atriplex canescens*
MT, ND	*Atriplex confertifolia*
MT, ND, SD	*Krascheninnikovia lanata* (synonym of/reported as *Ceratoides lanata* in ND, SD)
ND, SD	*Chrysothamnus nauseosus*
ND	*Chrysothamnus* sp.
ND, SD	*Gutierrezia sarothrae*
ND, SD	*Opuntia fragilis*
ND, SD	*Opuntia polyacantha*
ND	*Opuntia* sp.
ND	*Rhus aromatica* var. *trilobata*
ND	*Rosa arkansana*
MT	*Sarcobatus vermiculatus*
ND	*Suaeda moquinii*
ND, SD	*Symphoricarpos occidentalis*
ND	*Fraxinus pennsylvanica* [in vicinity not associate]
ND	*Ulmus americana* [in vicinity not associate]
ND	*Salix* spp. (reported as willows) [in vicinity not associate]
Life form: Forb	
State	**Species**
ND	*Achillea millefolium*
MT, ND, SD	*Allium textile*
SD	*Artemisia campestris*
ND	*Artemisia ludoviciana*
ND	*Aster ericoides*
SD	*Astragalus racemosus*
ND	*Astragalus bisulcatus*
ND	*Astragalus missouriensis*
ND, SD	*Atriplex argentea*
ND, SD	*Atriplex dioica*
ND	*Atriplex subspicata*
MT	*Atriplex suckleyi*
ND	*Campanula umbellata*
ND	*Chenopodium album*
ND, SD	*Comandra umbellata*

Table 3 (cont.).

State	Species
SD	*Cryptantha celosioides* [reported as "*Cryptandra celosioides*"]
ND	*Echinacea angustifolia*
ND, SD	*Eriogonum pauciflorum*
ND	*Euphorbia* sp. (prostrate species)
ND	*Euphorbia spathulata*
ND, SD	*Grindelia squarrosa*
ND	*Helianthus petiolaris*
ND	*Helianthus* sp.
ND	*Hymenoxys richardsonii*
ND, SD	*Iva axillaris*
ND, SD	*Kochia scoparia* (introduced)
ND	*Lactuca* sp.
ND	*Lappula redowskii*
SD	*Lepidium densiflorum*
SD	*Linum rigidum*
ND	*Lomatium foeniculaceum* [indicated to be tentative identification of vegetative plants]
SD	*Lotus purshianus*
ND, SD	*Machaeranthera canescens*
ND, SD	*Melilotus officinalis* (introduced)
ND	*Melitotus* sp. (introduced)
SD	*Mirabilis linearis*
ND	*Mirabilis nyctaginea*
MT, ND, SD	*Musineon divaricatum*
MT, ND, SD	*Oenothera caespitosa*
ND	*Orobanche ludoviciana*
ND	*Orthocarpus luteus*
ND	*Penstemon* sp.
ND	*Phlox hoodii*
ND	*Plantago elongata*
SD	*Plantago patagonica*
ND	*Plantago patagonica* var. *patagonica*
ND	*Plantago patagonica* var. *spinulosa*
SD	*Polygonum ramosissimum*
ND	*Polygonum* sp. (reported as knotweed)
ND	*Ratibida columnifera*
ND, SD	*Salsola iberica* (introduced) [synonyms: *Salsola kali*, *S. tragus*]
ND	*Salsola* sp.
ND	*Solanum rostrata*
ND, SD	*Solanum triflorum*
ND	*Solidago missouriensis*
ND, SD	*Sphaeralcea coccinea*
ND	*Tragopogon dubius* (introduced)
ND	*Vicia americana*

Table 3 (concluded).

Life form: Graminoid	
State	**Species**
ND, SD	*Agropyron caninum*
ND	*Agropyron cristatum* (introduced)
MT	*Agropyron dasystachyum*
ND, SD	*Agropyron smithii*
ND	*Agropyron* sp.
ND	*Andropogon scoparius*
ND	*Bouteloua curtipendula*
ND, SD	*Bouteloua gracilis*
ND	*Bromus inermis* (introduced)
ND, SD	*Bromus japonicus* (introduced)
ND	*Bromus tectorum* (introduced)
ND	*Buchloe dactyloides*
ND	*Calamovilfa longifolia*
ND	*Carex filifolia*
ND, SD	*Distichlis spicata*
ND, SD	*Hordeum jubatum*
ND	*Koeleria pyramidata*
ND	*Muhlenbergia cuspidata*
MT, ND	*Oryzopsis hymenoides*
SD	*Oryzopsis micrantha*
ND	*Poa pratensis* [in drainages near *E. visheri* but apparently not associate]
ND, SD	*Poa sandbergii*
ND	*Puccinellia nuttalliana*
ND, SD	*Schedonnardus paniculatus*
MT, ND	*Sitanion hystrix*
ND	*Sporobolus cryptandrus*
ND	*Stipa comata*
ND	*Stipa viridula*

Flowering pattern

Eriogonum visheri has been described as indeterminate (Ode 1987). This suggests that all plants within an occurrence will have the same likelihood of flowering at the same time throughout the season and a random-mating model could be assumed. However, studies of another annual *Eriogonum* species suggest that *E. visheri* may have a more complicated mating system. Fox (1989, 1990) studied *E. abertianum*, a desert annual in which some individuals flower in April–May, some in August–September, and some in both seasons. The consequence of the differences in flowering time is that some individuals within an occurrence cannot mate with one another. It is not clear from the information available if *E. visheri* plants exhibit this bimodal flowering pattern. However, the consequences of within-occurrence bimodal flowering pattern may be quite profound. By restricting gene flow between phenologically distinct groups of plants, Fox (2003) hypothesizes that assortative mating may make it easier for correlated adaptations to evolve. For example, early- and late-flowering individuals within an occurrence may confront different weather conditions, herbivores, and pathogens (Fox 2003). Early-flowering plants may be particularly vulnerable to frost damage whereas late-flowering plants may be susceptible to heat stress. Evolution of early-flowering, frost-hardy individuals and late-flowering, heat-resistant individuals might be difficult in a random-mating population, but assortative mating might make it easier (Fox 2003). In the *E. abertianum* studies, onset of flowering appears most often to be gamma (asymmetrically) distributed (Fox 1990, 2001, 2003).

Pollination biology

Eriogonum visheri has perfect (hermaphroditic) flowers and is expected to be able to self-pollinate (Ode 1987, Reveal personal communication 2005a). However, controlled tests to confirm that *E. visheri* is self-pollinated have not been conducted, and it may well be an obligate outcrosser. The ability to self-pollinate (autogamy) is common among annual plants and tends to ensure another generation if cross-pollination is poor in certain years. *Eriogonum visheri* has been reported to exhibit protandry, in that some of the male parts (anthers) of the flower reach maturity prior to the female organs (Ode 1987, Reveal personal communication 2005a). Professor Reveal (Ode 1987, Reveal personal communication 2005a) reports that the floral phenological pattern for many annual *Eriogonum* species is as follows. The tepals open the first day, and the six outer anthers typically ripen and dehisce. In the evening, the tepals close, but the filaments hold the anthers outside the closed tepals. On the second day, the three remaining anthers mature. Also on the second day, the stigma opens out and becomes receptive (sticky). During this time, it is receptive to pollen carried by arthropods or wind (Reveal personal communication 2005a). At the end of the second day, the anthers are then forced into contact with the receptive stigma as the tepals close in the evening of the second day. This ensures selfing if pollen from other sources is absent or in very low quantities (Reveal personal communication 2005a). This proposed sequence of events need to be confirmed for *E. visheri*.

The pollen grains of *Eriogonum* species are generally trinucleate, tricolporate, scabrate, and roughly oval in shape (personal observation by the author, USDA Southern Plains Agricultural Research Center 2001, Geography@Berkeley! 2005). Pollination studies specifically on *E. visheri* have not been conducted. The flowers of *E. visheri* are very small (1.2 to 1.8 mm long) and may be wind-pollinated (Ode 1987, Reveal personal communication 2005a). *Eriogonum visheri* pollen also may be carried by small bees, flies, bee-flies, or perhaps ants (Reveal personal communication 2005a). It is not known if the small flowers of *E. visheri* are attractive to any specific pollinator arthropods. A significant problem in deducing the pollination syndrome of *E. visheri* from studies of other *Eriogonum* species is that there is a very wide variation in flower size, flower color, and flower density for an inflorescence within the genus *Eriogonum*. In addition, flowering phenologies, which are important to both pollinator species and pollination timing, also vary widely between *Eriogonum* species (Peterson 1997, Fox 2003). Another consideration is that factors including life form (annual versus woody perennial versus herbaceous perennial) and habitat may influence pollination syndrome. As an example of this diversity, *E. longifolium* var. *gnaphalifolium* (synonym *E. floridanum*) is a long-lived perennial endemic to central Florida. This taxon has larger flowers (6 to 8 mm long) than *E. visheri* and is pollinated by wasps, flies, and solitary bees, but an individual plant presents only one or a few flowers at any one time (Menges and Quintana-Ascencio 2002). Therefore, it is likely that little of the pollination biology of this species will directly apply to *E. visheri*.

Eriogonum species with more conspicuous corollas than *E. visheri* are clearly insect-pollinated, especially by flies and native bees (Neel et al. 2001, Menges and Quintana-Ascencio 2002, Reveal 2005). Pollinators of *E. ovalifolium* include members of the order *Diptera* (flies) in the families Bombyliidae, Chloropidae, Muscidae, Tachinidae, and Anthomyiidae and of the order *Hymenoptera* (bees, wasps, and ants) in the family Halictidae (Neel et al. 2001). Butterflies (Order Lepidoptera), particularly species of *Euphilotes*, are also pollinators of some *Eriogonum* species (Reveal 2005b). *Euphilotes enoptes* pollinates *Eriogonum compositum*, a long-lived perennial species with relatively large (5 to 6 mm) flowers (Reveal 2005b). Ants are important in both self- and cross-pollination of the perennial *E. pelinophilum*, but they apparently rarely pollinate annual *Eriogonum* species (Reveal 2005b, Reveal personal communication 2005a).

Relationships between arthropod species, which may not be fully understood, pose a potential complication in interpreting their roles in the ecology of *Eriogonum* species. For example, ants tend *Euphilotes enoptes* larvae (Peterson 1997). Therefore, the behavior of ants may be strongly influenced by the behavior of *E. enoptes*.

In general, potential pollinators visit *Eriogonum* species in the late morning and early afternoon (Reveal personal communication 2005a). However, visitation times vary greatly, and a dawn to dusk study is necessary to know the pollination timing of *E. visheri*. Another important aspect to the reproductive biology of *E. visheri* is that pollen transfer events may be of limited value for genetic flow if pollen from one flower is only successfully moved to another flower on the same plant (geitonogamy). Geitonogamy (between-flower self-pollination) provides no reproductive assurance and can cause severe seed and pollen discounting[3] (Eckert 2000).

Hybridization

Eriogonum species have been reported to hybridize in nature (Stokes 1936). Stokes (1936) believed that geographic isolation is an important factor in preserving many *Eriogonum* species from intergradation. Even so, no evidence of hybridization between *E. visheri* and sympatric *Eriogonum* species has been reported. This lack of hybridization is consistent with a short-distance transfer of pollen, among other things. Other factors that may contribute to genetic isolation of potential parents and hybrid progeny include pollinator preferences, temporal separation of flowering periods, and/or spatial separation of the different species (Grant 1981).

Size and plant density

The average size of *Eriogonum visheri* individuals has been reported to differ within and between occurrences (Ode 1987, Schmoller 1993, 1995, Montana Natural Heritage Program 1997-2004, Vanderhorst et al. 1998; see Habitat section). Size of individuals within a population is an important aspect of population structure because it plays an important role in reproductive output and differential survivorship (Sarukhan et al. 1984). In general, larger plants produce more offspring and have a better survival rate compared to smaller plants of the same species (Sarukhan et al. 1984). Population density as well as environmental conditions may contribute to the differences in plant size (Silvertown 1987). Plants that are densely distributed may have access to fewer resources (e.g., minerals and water) than sparsely distributed individuals may. Research on *Arabidopsis thaliana* indicated that the density at which plants grew critically influenced seed production and seed dispersal (Wender et al. 2005). Changes in density also led to changes in the plant traits exhibited, in maternally inherited traits, as well as in seed dispersal characteristics (Wender et al. 2005). The Wender et al. (2005) findings that there are density-dependent relationships between plant traits, dispersal, and maternal fitness suggest that the variable densities of *E. visheri* colonies may be important in their ability to adjust to fluctuating environmental conditions. In this case, extrinsic factors such as disturbance that affect the size and density of *E. visheri* colonies may have more important population fitness implications than are currently realized.

Seed biology

There are no data specific to the seed biology of *Eriogonum visheri*. This species grows in environments with wide temperature fluctuations, long drought periods, and erosive soils. Upon drying, the soils tend to form deep cracks or fissures. In these environments, seeds may be "self-planted" by falling into the cracks that close when wetted, thus covering the seeds. Some species of desert annuals exhibit some type of innate dormancy in which a fraction of the seeds remain dormant in any one season even if growing conditions are optimal. This mechanism can provide protection against depletion of the seed bank in the event that successful reproduction cannot be accomplished in any given year (Freas and Kemp 1983, Silvertown 1987). Seeds of a winter annual and several perennial *Eriogonum* species have a temperature-controlled component to dormancy (Baskin and Baskin 1989, Kemp 1989, Meyer and Paulsen 2000). Other *Eriogonum* species have been observed to have a higher rate of seed germination in the light. By extrapolation, there might also be a light component to dormancy control in *E. visheri* seeds (Baskin and Baskin 2001). It is possible that seeds in the seed bank respond to light introduced by the shrink-swell cracking of the substrate. The localized, often subtle, disturbance regime of badland soils may be important and contribute to the patch dynamics of the species.

Given the uncertainties of reproducing adequately every year, a persistent seed bank is likely to be a requirement for the long-term persistence of *Eriogonum visheri*. Many annual vascular species in deserts and semi-deserts where conditions are unstable, the precipitation is variable, and relatively long droughts are frequent, have seeds with substantial longevity in a well-stocked seed bank (Moseley 1989). Another annual *Eriogonum*, *E. annuum*, had one of the largest seed banks in the Nebraska sandhills, but annual germination was less than 6 percent (Perez et al. 1998). This observation suggests that many of the seeds were dormant, supporting the hypothesis that annual *Eriogonum* seeds have an innate dormancy.

Seed dispersal

The reasons behind the observed patchy distribution of *Eriogonum visheri* seed have not been studied. However, the aggregated spatial distribution of plants suggests that many seeds may land within a short distance form the parent plant(s) due to gravity. It is not

[3]See **Definitions** section for the definition of seed discounting and pollen discounting.

known if restricted seed dispersal is a significant reason for the small amount of apparently suitable habitat that is occupied.

Dispersal mechisms of *Eriogonum visheri* seeds have not been studied in detail. The seeds are most likely dispersed by surface run-off (Ode 1987). Stokes (1936) observed that in general, seeds of *Eriogonum* species similar to *E. visheri* were easily transported by run-off, which tended to deposit them at the base of cliffs and bluffs and on alluvial fans. *Eriogonum visheri* grows in all of these areas. Observations that *E. visheri* plants are most frequently established in microdrainages and places where water would accumulate, if only fleetingly during a rain event, also support the idea that seeds are commonly transported by water. However, it may be that plants become established only in these areas. It is not known how many seeds germinate in areas where plants do not become established. Conditions for successful germination may be different from the conditions needed for successful seedling establishment. For a wind-dispersed *Artemisia* species in a sandy habitat, seed deposition did not determine the spatial pattern of seedling recruitment (Li et al. 2005).

Other agents of *Eriogonum visheri* seed dispersal may include wind, birds, arthropods, and mammals. Ruderals tend to have numerous small wind-dispersed seeds (Grime et al. 1988). In general, wind-dispersed seeds move only short distances, and this is consistent with the clustering and patchy nature of *E. visheri* occurrences (Silvertown 1987). Based on his field observations, Ode (1997) suggested that resident and migratory passerine birds might help disperse *E. visheri* seeds. Although grain-eating birds digest seeds very thoroughly, seeds of members of two other genera in the Polygonaceae, *Rumex* and *Polygonum*, apparently escaped digestion and went on to germinate when collected from the excreta of finches (Ridley 1930). Large mammals can disperse seeds, either on their hooves or fur or after ingestion (Ocumpaugh et al. 1996, Sheley and Petroff 1999, Cosyns et al. 2005). Under wet conditions, badlands clay can cling to animal hooves, providing a potentially good medium by which to transport seeds. Livestock have been found to be instrumental in dispersing many vascular plant species (Sheley and Petroff 1999, Cosyns et al. 2005). While possibly due to other factors, it may be notable that many *E. visheri* occurrences are found along cattle trails (**Table 1**, **Table 2**). Although granivores generally have a significant impact on desert seed banks (Kemp 1989), no evidence of either arthropod or mammalian granivory has been documented for *E. visheri* seed.

Life strategy

Being a summer annual species growing in an unstable habitat, *Eriogonum visheri* has several of the characteristics that match the profile of an r-selected species (MacArthur and Wilson 1967). "Unstable habitat" in this context refers to environmental conditions associated with the habitat such as unpredictable temperature and precipitation and erosive soils. The known characteristics of its morphology and life history fit into the model of a ruderal species developed by Grime et al. (1988), and from this type of model, other characteristics may be inferred. Grime et al. (1988) described ruderal species as depending on a persistent seed bank of numerous small, wind-dispersed seeds with seasonal regeneration in vegetation gaps. Considering what is known, these characteristics are likely to apply to *E. visheri*, but further studies need to be conducted to confirm these conclusions.

Demography

Eriogonum visheri plants occur in colonies that range in size from fewer than 10 individuals to several thousands (**Table 1**, **Table 2**; see Distribution section). Because there are few details on germination, survivorship, fecundity, and dispersal of *E. visheri*, only a generalized life history diagram has been developed (**Figure 6**). Superficially, the life cycle diagram of this short-lived annual is quite simple. Heavy arrows indicate the basic life cycle, and dashed arrows and bordered question marks indicate that specifics are unknown.

There are gaps in knowledge that are critical to estimating the long-term sustainability of *Eriogonum visheri* occurrences. Levels of recruitment and mortality at all stages of growth and development have not been identified. The balance between recruitment of seeds to the seed bank, seed abortion rate, size of the annual seedling pool, and mortality before seed maturation are unknown. There are also no data on seed longevity or seed bank dynamics. Although transition probabilities between one stage and the next are unknown, annual variation in population size and unpredictable environmental conditions probably result in considerable variation in transition probabilities from year to year.

There have been no documented analyses of *Eriogonum visheri* population matrices. Because it is an annual plant growing in unpredictable environments, two critical parts of its life cycle would intuitively

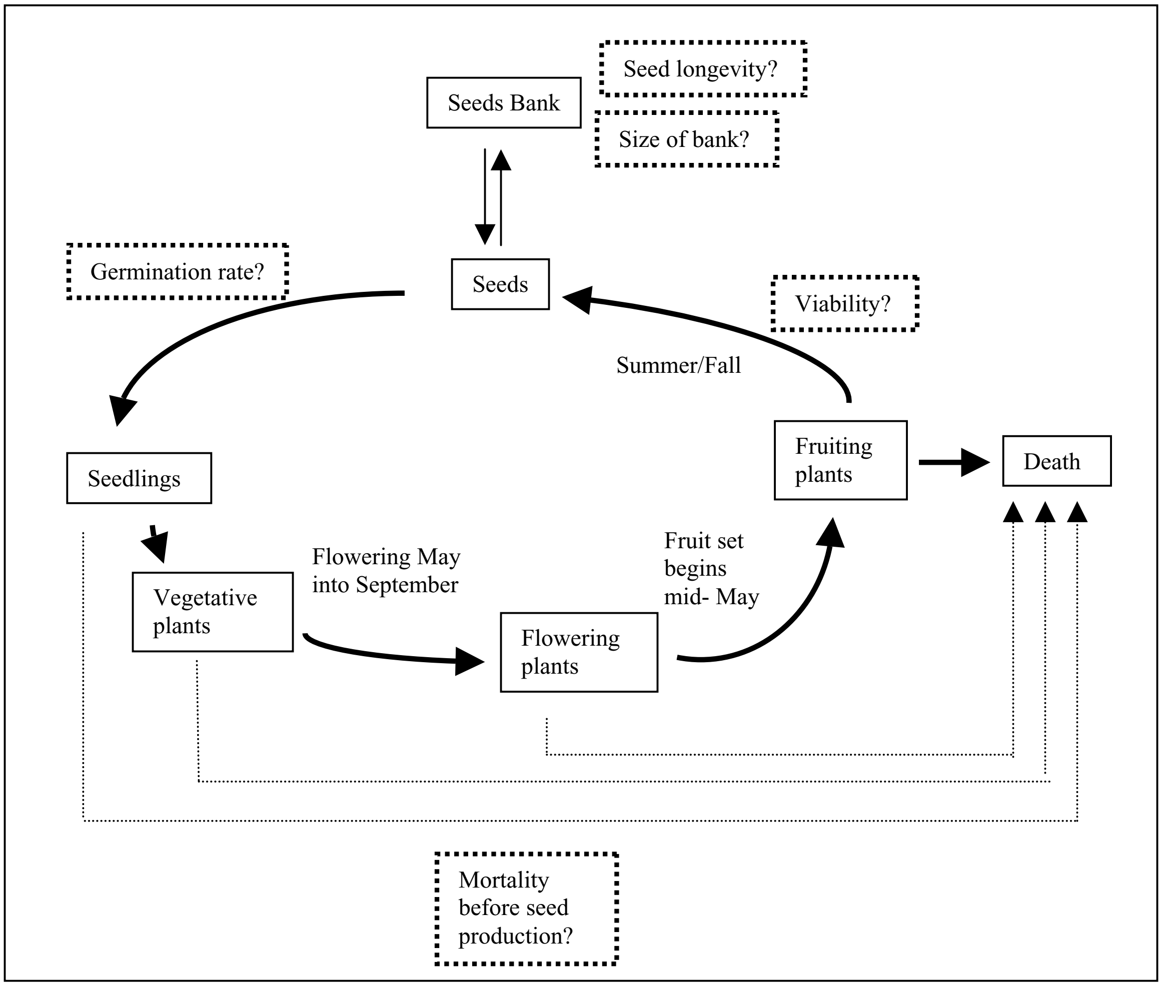

Figure 6. Simple life-cycle diagram for *Eriogonum visheri*. Dashed lines and boxes indicate that the events need to be confirmed.

appear to be seed production and a viable and long-lived seed bank. Intense disturbance that leads to soil and seed bank removal or high levels of seed predation above the evolutionary norm can be predicted as being particularly devastating to local populations. The contributions of recruitment and fecundity are also likely to be critical to overall survival and the maintenance of genetic diversity. These deductions are partially supported by the results of population viability analysis of an annual thistle (*Carduus nutans*) in a part of New Zealand that often suffers harsh, dry summers. The derived elasticity matrix reflected an overwhelming importance of the seed bank and of seedling recruitment to the growth of the population (Shea and Kelly 1998). The emphasis was also on flowering early at smaller sizes, albeit with lower fecundities (Shea and Kelly 1998).

Depending upon the size of the seed bank, temporal variation in *Eriogonum visheri* population size may be due to environmental conditions of preceding years influencing seed production as well as of the current year, which influences germination and seedling establishment. *Eriogonum visheri* colonies tend to be observed predominantly in micro-drainages and outwashes, which may be a consequence of seed dispersal. However, the degree to which these sites provide the necessary microhabitat for seed germination and successful seedling establishment has not been determined (see Reproductive biology and autecology and Habitat sections).

There is no information on the genetic diversity among populations of *Eriogonum visheri*. Locally endemic species tend to exhibit reduced levels of polymorphism that may imply genetic vulnerability (Karron 1991). However, while rare species can have statistically less genetic variation than their widespread congeners, there is a large range in values and some rare species exhibit levels of diversity equal to, or exceeding, that of widespread congeners (Gitzendanner and Soltis

2000). The high amount of genetic variability in an extremely rare herbaceous perennial, *E. apricum* (Ione buckwheat), caused Stebbins (1980) to reverse his initial opinion that rare species had little genetic variability (Stebbins 1942). Archibald et al. (2001) examined the genetic structure of the only known population of the perennial *E. ovalifolium* var. *williamsiae* (Steamboat buckwheat), which is a subshrub endemic to Washoe County, Nevada. The results from analysis of patterns of allozyme variation suggested that *E. ovalifolium* var. *williamsiae* has high genetic variability, with levels of variation similar to that of a widespread species rather than of a narrow endemic (Archibald et al. 2001). Gitzendanner and Soltis (2000) reported that levels of observed heterozygosity were strongly correlated within a genus. Although both *E. apricum* and *E. ovalifolium* var. *williamsiae* are perennial taxa and extremely restricted in their distribution, this correlation suggests that *E. visheri* may have substantial genetic variation. More information specifically for *E. visheri* is needed to confirm this theory.

What constitutes an interbreeding group of *Eriogonum visheri* plants also cannot be delineated with confidence, because information on seed dispersal and pollination biology is lacking (see Distribution and abundance section). Some aspects of the biology and ecology of *E. visheri* suggest that long-distance pollen transfer events may be infrequent. Although arthropod pollinators have the potential to carry pollen long distances, there may well be density-dependent aspects to successful cross-pollination because some pollinators are density-dependent foragers (Geer and Tepedino 2000). Therefore, occurrences with a low density of *E. visheri* flowers may be at a disadvantage. Even if plants are visited, the abundance of *E. visheri* pollen on the vector may be relatively low and statistically overwhelmed by more abundant pollen from other plant species. Conversely, if small patches of *E. visheri* plants are separated by landscapes occupied by only a few patches of entomophilous flowering plants, competition from other species for pollinators would be less likely.

Another factor to consider is that the nectar and pollen reward ("attractiveness") of small *Eriogonum visheri* flowers relative to other flowers in its vicinity is unknown. This is also an important aspect of out-crossing success of entomophilous species. These considerations and the observations that pollen is rarely moved between populations of certain other *Eriogonum* species (Reveal personal communication 2005a) suggest that widely separated *E. visheri* occurrences may represent isolated unique ecotypes adapted to local conditions (see Reproductive biology and autecology section). More study is needed to answer these questions and understand the genetics and demographics of *E. visheri*.

No analyses of population viability for *Eriogonum visheri* have been documented, and the minimum viable population size is unknown. From a genetic perspective, natural populations often behave as if they were smaller than a direct count of individuals would suggest (Barrett and Kohn 1991). The most intensive studies of minimum viable population size have been conducted on animal species, but many of the same principles underlying population sustainability analysis apply to plant populations as well. Considering the long-term viability of a population, Franklin (1980) and Lande and Barrowclough (1987) concluded that an effective population size of approximately 500 individuals was sufficient to maintain evolutionary potential in quantitative characters under the shifting balance of the evolutionary forces of mutation and random genetic drift. Lande (1995) cited experiments that indicated that "the rate of production of quasineutral, potentially adaptive genetic variance in quantitative characters is an order of magnitude smaller than the total variance" added through mutation, and suggested that the minimum effective population size should be an order of magnitude higher, approximately 5,000 individuals. Franklin and Franklin (1998) questioned this number on the basis that many estimates of the required mutational variance already partially accounted for deleterious mutations and that heritabilities are often lower than the 50 percent value used by Lande (1995). After accounting for both these points, the estimated effective population size reverted to nearer 500 (Franklin and Franklin 1998). However, it is likely that the minimum viable population size will vary significantly from 500 and may approach 5,000 depending on differences in inherent variability among species, demographic constraints, and the evolutionary history of a population's structure (Frankham 1999).

Community ecology

Few experimental data have been gathered on the community ecology of *Eriogonum visheri*. Much of the information available is descriptive and was gathered during floristic surveys. The information presented in this section includes observations of aspects of community structure, the successional position of *E. visheri*, possible interactions of *E. visheri* with different animal species, vascular plant competition, and the effects of disturbance on *E. visheri*.

Community structure

Eriogonum visheri grows in areas with low vegetative cover but with a diversity of associated vascular plant species (**Table 3**). No information is available describing the microbiotic community associated with *E. visheri*. The microbiotic community on the soil surface refers to the biological soil crust that includes lichens, mosses, fungi, cyanobacteria, and algae. This is quite different from the physical inorganic crusts formed by interaction between the soil and environmental processes such as the impact of raindrops. Microbiotic crusts can provide physical benefits, such as reducing soil erosion from water and wind, and provide suitable microhabitats for seed germination and seedling establishment (Ladyman and Muldavin 1996, Belnap et al. 2001). They can also provide ecological benefits, such as providing nitrogen and carbon to the soils (Ladyman and Muldavin 1996, Belnap et al. 2001). A survey for lichens and lichenicolous fungi was made in the Badlands National Park (Will-Wolf 1998). Lichens were collected from three diverse substrates: calcareous rock, bark and wood, and soil (Will-Wolf 1998). Species were collected from soils that included those on sparsely vegetated slopes and flats of Brule mudstone and Pierre shale formations, suggesting that some species are associated with *E. visheri* (Will-Wolf 1998). During this survey, it was noted that 31 species of lichen grew on soil in these areas (Will-Wolf 1998). Although the information was in insufficient detail to know which species were specifically associated with *E. visheri* habitat, it was unlikely to be all of the 31 species, since some (e.g., *Peltigera rufescens* and *Cladonia chlorophae*) are likely to grow in more vegetated regions under different edaphic conditions than *E. visheri*. More likely associates in Will-Wolf's collection (1998) included some *Catapyrenium* species and *Collema tenax*. As well as aiding in soil stabilization, the latter can fix nitrogen in the soil (Ladyman and Muldavin 1996).

Successional position

Eriogonum visheri appears to be adapted to the shrink-swell action that characterizes soils in its habitat. These soils tend to expel many of the plants that grow on them. Because of this soil characteristic, susceptibility to erosion, and low vegetation cover, the sites that support *E. visheri* are typically in a pioneer state of development. *Eriogonum visheri* has many of the attributes of a ruderal species (see Reproductive biology and autecology section). It is a small, potentially fast-growing, rapidly flowering annual (Grime et al. 1988). Considering the relatively barren and unstable environmental conditions it inhabits, *E. visheri* may be described as an early successional species (Diller 2002; see Habitat section). However, *E. visheri* is found at sites characterized by a sparse vegetative cover that likely represents a natural "climax" condition maintained by the edaphic properties, harsh environmental factors, and occasional severe erosion events resulting from downpours and wind. Therefore, *E. visheri* may not represent an early successional species in the classical sense but rather one that occupies a specialized ecological niche. This alternative view of the taxon may influence some human perception of its position within the community. "Early successional" suggests a taxon that is eventually replaced, whereas one that is "part of a climax community" suggests permanence and greater importance in the ecosystem.

Wildlife and livestock

The role of *Eriogonum visheri* in the badland ecosystem is not precisely defined (Ode 1987). It probably serves as an important food source for some wildlife species and may provide cover or support for certain arthropods. Ruderal species generally have very high palatability to unspecialized herbivores (Grime et al. 1988). In years of abundance, *E. visheri* plants could be significant source of food for small mammals, birds, and insects (Ode 1987). Plants found in South Dakota in sites inaccessible to livestock had apparently been grazed by wildlife, possibly including least chipmunks (*Eutamias minimus*; Ode 1987). Least chipmunks, as well as desert cottontails (*Sylvilagus auduboni*), rock wrens (*Salpinctes obsoletus*), and Say's phoebes (*Sayornis saya*), are much more frequently encountered in badlands than in the surrounding grasslands (Ode 1987).

Eriogonum species may be an important part of the diet of many birds. In particular, Baird's sparrow (*Ammodramus bairdii*) was observed plucking mature involucres from *E. visheri* plants in South Dakota (Ode 1987). In Oregon, an unidentified *Eriogonum* species was found to be a primary forb in the diet of pre-laying sage grouse (*Centrocerus urophasians*; Barnett and Crawford 1994). Birds may also contribute to seed dispersal (see Reproductive biology and autecology section).

Eriogonum visheri occurrences are rarely dense enough to provide substantial forage for livestock (Ode 1987). However, livestock are likely to use *E. visheri* incidentally. *Eriogonum visheri* may also contribute to a small extent to the diet of pronghorn (*Antilocapra americana*). *Eriogonum visheri* is unlikely to be a major source of browse, but when available it may well be used because pronghorn prefer forbs in addition to cool-season grasses (Mack and Thompson 1982). The palatability of *Eriogonum* species is difficult to predict. Palatability depends upon both the species of herbivore and the species of *Eriogonum*. In Arizona and New Mexico, pronghorn avoid some *Eriogonum* species (Miller and Drake 2003) and include others in their diet (Biota Information System of New Mexico BISON 2004).

The relationship between butterflies and *Eriogonum* species appears complex and varies according to species. Adults of some butterfly species sip the nectar of *Eriogonum* species and function as pollinators, while others use *Eriogonum* species as a host on which to lay eggs (Scott 1997). In other cases, the benefits are reciprocal and the butterfly serves as a pollinator while the plant serves as food and shelter to its larvae (Scott 1997). Larval-plant associations are often species specific (Scott 1997). It may be that some associations between butterfly and *Eriogonum* species represent examples of parallel speciation. However, this cannot be assumed without further study. Analyses of *Euphilotes* populations, using biochemical, morphological, and life history characters, did not support either coevolution or sequential evolution with *Eriogonum*, and the results were more consistent with opportunistic adaptation to new hosts having different bloom periods (Pratt 1994).

Three butterfly species have been reported associated with *Eriogonum* species on the Little Missouri Grassland (Royer 1995-1996). The *Eriogonum* species were not reported, but the habitat description suggested that two of the butterfly species might visit *E. visheri*. Acmon Blue (*Icaricia acmon*) was found on the "*Eriogonum* flats along upper slopes in badlands, where it patrols and takes nectar at its presumed larval host, *Eriogonum*" (Royer 1995-1996). Another species, *Cercyonis meadii* (Mead's wood nymph), was observed in "badlands canyons, often found with the second brood of *I. acmon* at the blooms of *Eriogonum* on eroded badlands slopes," but *Eriogonum* species were not the larval food in this case (Royer 1995-1996).

Spiders (suborder *Labidognotha*) frequently build webs in mature *Eriogonum visheri* plants, and inchworms (Order *Lepidoptera*, Family Geometridae) occasionally pose as branches in the inflorescence (Ode 1987). The significance of these observations to the functioning of the ecosystem is unknown. Parallels in speciation between arthropods and habitat-specialist plant species, such as *E. visheri*, generally need much more research (see Reproductive biology and autecology section). At the current time, other than in cases where there is a direct economic consequence such as crop pest management, there is relatively little understanding of the myriad interactions between plants and invertebrate animals.

Vascular plant competition

The sparsely vegetated, open habitat in which *Eriogonum visheri* has evolved suggests that it is not adapted to be an effective competitor for water, light, and/or nutrients. Its small stature also suggests that it is particularly vulnerable to shading. *Eriogonum visheri* has apparently been excluded from several historical occurrences where grass or aggressive forbs appeared to be encroaching (**Table 1**, **Table 2**). An observation made at SD - 15 (**Table 1**) noted that *Salsola kali* (tumbleweed) was present and dense in adjacent apparently suitable but unoccupied habitat. It was also observed that *E. visheri* plants were small and of low vigor in a site that was especially weedy (Diller 2002). These observations must be interpreted cautiously because it is unknown how long the sites had been weedy or what the population's condition was before weeds colonized the site.

Disturbance

The role of disturbance in the life history of *Eriogonum visheri* is not understood and probably depends upon the type, severity, and extent of the disturbance. Several common annual *Eriogonum* species will colonize disturbed areas, and *E. annum* has been classed as a weedy species in Nebraska and other Great Plains states (Stubbendieck et al. 1994). However, extrapolations from the colonizing habit of a common species to that of a rare one cannot be made since frequency of occurrence and range are key factors that distinguish the two species. Disturbance that appears likely to be biologically beneficial to the life cycle of *E. visheri* and potentially involved with maintenance of its habitat is the natural shrink-swell cracking in the soil and redistribution of sediment by run-off across the badlands landscape. Gross disturbances caused by anthropogenic activities are likely to have sometimes contradictory consequences. Disturbance, apparently of anthropogenic origin, has been proposed as important to the life cycle of *E. visheri* (Schmoller 1993, Washington personal communication 2005). This hypothesis appears to be largely based on observations that *E. visheri* grows in areas disturbed by human activity, such as ditching for pasture roads and along livestock trails (Schmoller 1993, Vanderpool

1993, Washington personal communication 2005). However, in North Dakota it has been observed that although *E. visheri* might initially colonize disturbed sites, the taxon is excluded as more aggressive weedy species invade the sites after two or three years (Washington personal communication 2005). These weeds do not typically invade the native habitats of *E. visheri* without anthropogenic disturbance. Therefore, it is very unlikely that artificial habitats created by anthropogenic disturbance will lead to sustainable populations (Washington personal communication 2005). The presence of *E. visheri* colonies along trails may be due to livestock being vectors of dispersal, as well as agents of disturbance.

Historically, bison (*Bison bison*) roamed through the badlands of the Great Plains (Bailey 1995), but their specific use of the *Eriogonum visheri* habitat type is not known. Bison were likely to have at least occasionally passed through areas occupied by *E. visheri* in transit between grasslands. Since both species are large bovine ungulates, domestic cattle (*Bos taurus*) may be considered as having replaced bison. However, cattle are not a direct substitute since bison utilize different species of plants than cattle and exhibit different foraging and social behaviors, leading to different disturbance patterns (Peden et al. 1974, Jones et al. 1993, Plumb and Dodd 1993). For example, compared to free-roaming bison, a larger number of individual domestic cattle typically graze a limited area for a longer time, and cattle do not create an environment as spatially or temporally diverse as that generated by bison (Laurenroth and Milchunas 1995, Benedict et al. 1996, Ostlie et al. 1997). This latter observation leads to speculation that bison may have been significant in maintaining the vegetation mosaic of the region. Audubon's bighorn sheep (*Orvis canadensis audubonii*) was also a native to the badlands but is now extinct (Ode 1987). Pronghorn is now the most abundant large mammal native to the area (Bailey 1995). There might be an opportunity to study the influence of large native mammals within *E. visheri* habitat in Badlands National Park, where bison and Rocky Mountain bighorn sheep (*Orvis canadensis*) have been re-introduced (Berger and Cunningham 1995). A comparative bison-cattle study could also take place on the Buffalo Gap National Grassland, where some allotments are open to bison, but are closed to cattle.

Ode (1987) noted that there are no colonies of *Eriogonum visheri* on sites with populations of bison, elk (*Cervus elaphus*), or bighorn sheep. However, it was not clear whether large herbivores led to the exclusion of *E. visheri* or if these areas were just never inhabited by the taxon. Rocky Mountain bighorn sheep were introduced into one area of the Dakota badlands, and apparently, although they increased in number, they did not expand outside the initial relatively small release area (Bourassa 2001). It is not known if *E. visheri* occurrences were ever in the area where the bighorn sheep were introduced.

Resources envirogram

A simple envirogram for *Eriogonum visheri* has been developed for this assessment (**Figure 7**). An envirogram is a graphic representation of the components that influence the condition of a species and reflects a species' chance of reproduction and survival. Envirograms have been used to describe the conditions of animals (Andrewartha and Birch 1984) but may also be applied to describe the condition of plant species. Those components that directly affect *E. visheri* make up the centrum, and the indirectly acting components formthe web (**Figure 7**, **Figure 8**). The envirogram in **Figure 7** is constructed to outline some of the major components believed to impact the species directly. Unfortunately, much of the requisite information to make a comprehensive envirogram for *E. visheri* is unavailable. Some evidence exists for the factors in closed boxes. Factors in dashed boxes are more speculative. Dashed crossed lines indicate hypothesized interactions. Environmental stochasticities that appear to affect survival and reproductive success of *E. visheri* include variation in precipitation and in the populations of arthropods, birds, and small mammals in their capacity as herbivores, granivores, and possibly pollinators. Precipitation, in the form of soil moisture, may contribute to variation in year-to-year abundance, and in the form of surface run-off, it may act to disperse seeds. The soil properties, both physical and chemical, to which *E. visheri* is adapted are apparently critical, but its specific requirements are not known. Soil temperatures or a combination of soil temperature and moisture may be a significant factor for successful germination.

CONSERVATION

Threats

Current evidence suggests that *Eriogonum visheri* across its range is particularly vulnerable to habitat loss because it has very specific but poorly understood habitat requirements. This taxon's range is apparently restricted by many more factors than underlying geology. The amount of suitable unoccupied habitat is currently unknown. Because of this, the

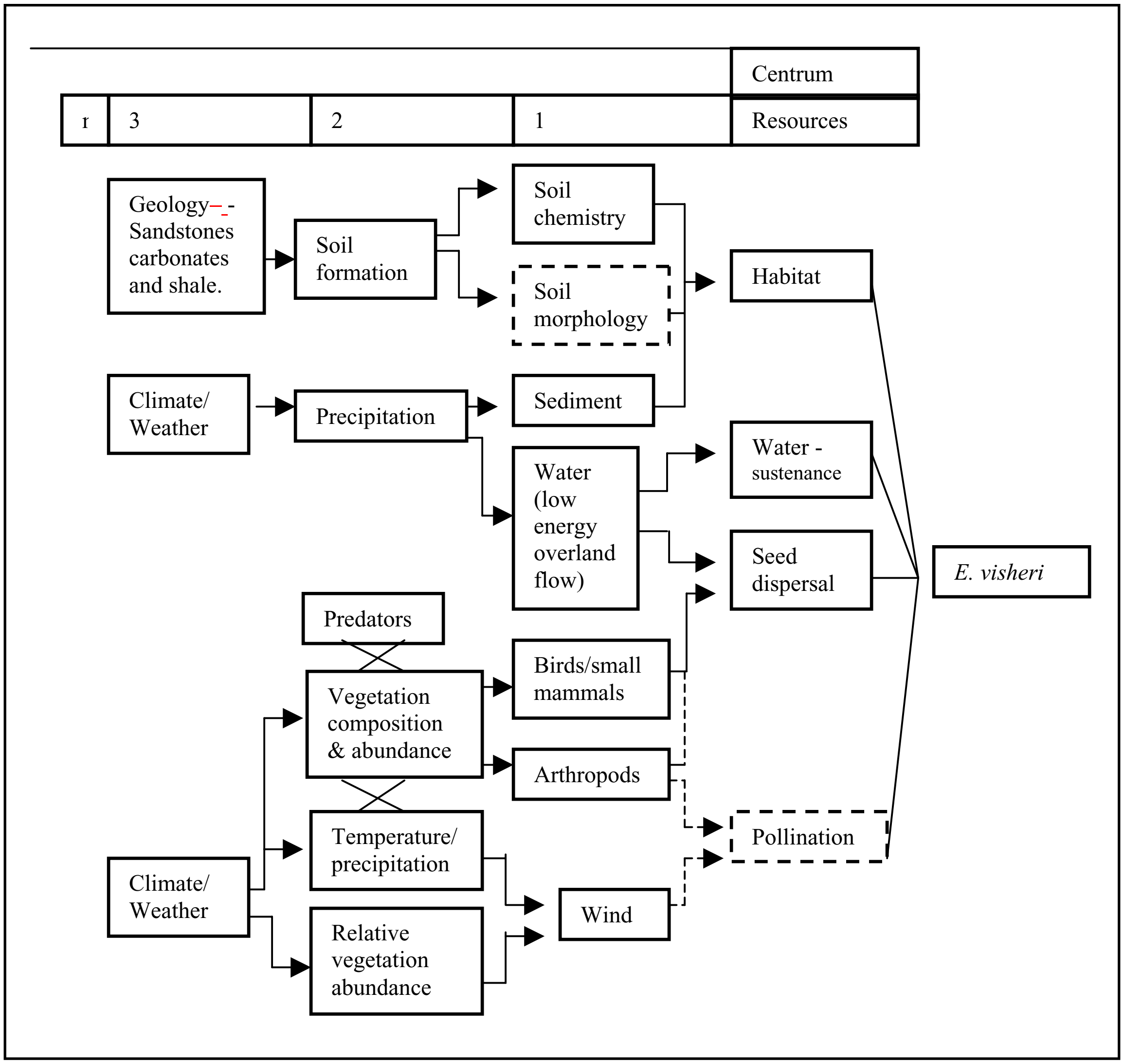

Figure 7. Envirogram illustrating some of the resources to *Eriogonum visheri*. Dashed lines indicate that the factors need to be confirmed.

amount of apparently suitable habitat that can be eliminated without having negative long-term impacts on *E. visheri* cannot be accurately estimated. The many agents that contribute to habitat loss include urbanization, land conversion for agriculture, resource extraction, livestock grazing, invasive non-native plant species, and recreation activities, especially those using motorized vehicles. Over half the occurrences of the species are on private or tribal lands. The conservation status, occurrence conditions, and threats on those lands are very poorly known.

In Region 2, livestock grazing, invasive non-native plant species, and recreation activities appear to be the most significant threats. Resource extraction activities currently are not perceived to be a substantial threat in Region 2. Although future land exchanges have the potential to further impact the distribution and abundance of *Eriogonum visheri*, direct impacts from urbanization and land conversion appear unlikely to pose serious threats to occurrences on Region 2 National Forest System land in the near future (Sargent personal communication 2006). Each threat or potential threat is discussed in more detail in the following paragraphs.

Urbanization, land conversion, and transportation infrastructure

Even though human populations in North and South Dakota are not growing as quickly as in other parts of the United States, urbanization and road construction remain an enduring process. Some counties in North Dakota experienced human population declines within the last decade, but these trends may be reversed in

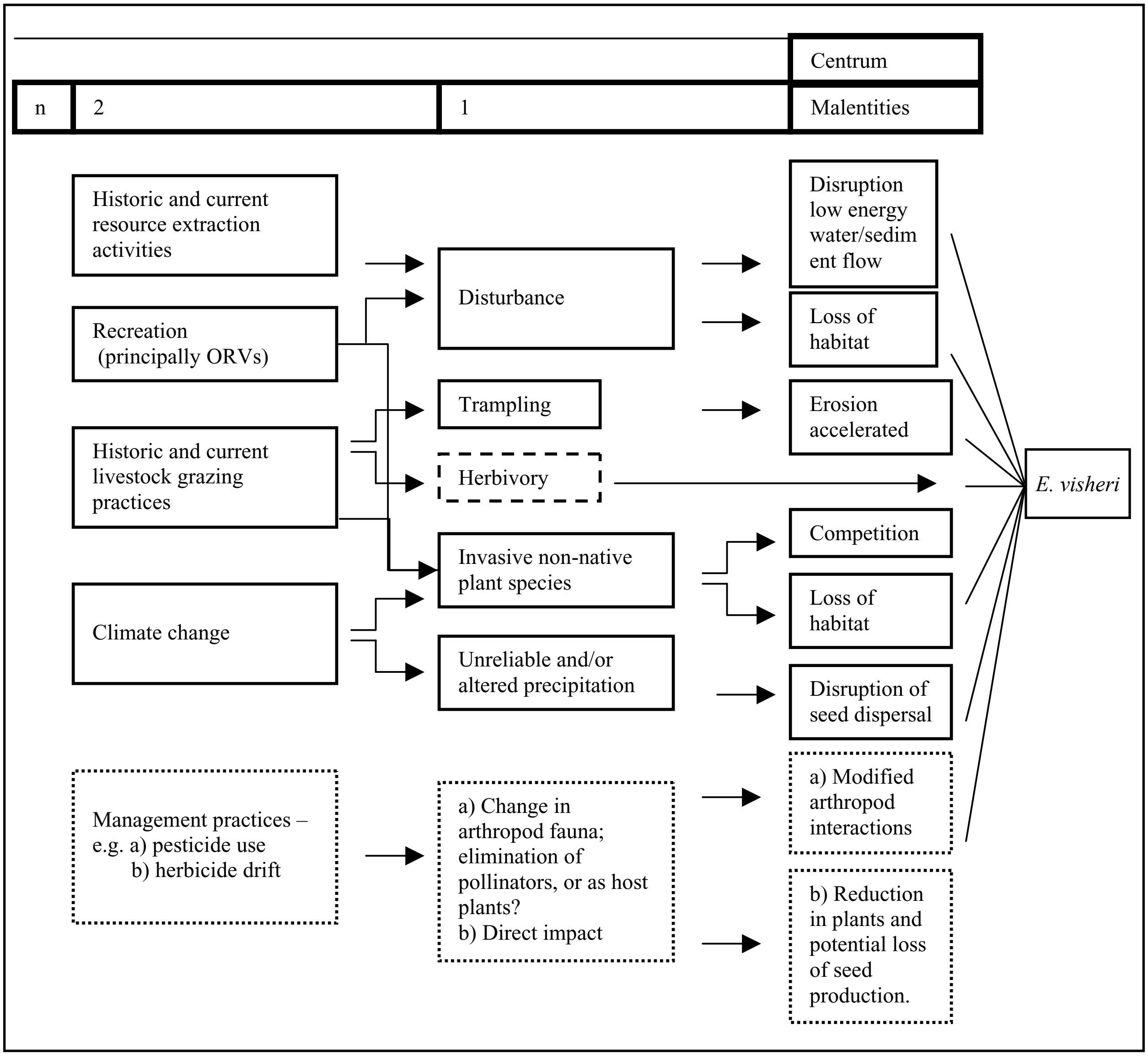

Figure 8. Envirogram illustrating some of the malentities and threats to *Eriogonum visheri*. Dashed lines indicate that the factors need to be confirmed.

the future (U.S. Census Bureau 2000). Future land conversion for crops will depend upon climatic conditions, available water, and economic incentives. Conversion to cropland has taken place at some historic occurrences. For example, Visher collected the type specimen near Meadow, South Dakota. Searches in this area in 1983 failed to find plants within a 2 mile area around the town, and the field researcher remarked that there was little appropriate habitat because the area had been converted to cropland (SD - 23 in **Table 1**).

The effects of urbanization extend beyond construction of homes and businesses. The infrastructure to support urban areas and recreational activities needs to be expanded. Road upgrades, widening, and right-of-way maintenance might affect occurrences that are near highways and roads (e.g., ND - 23 is near a county road and might be impacted by road upgrades; **Table 2**). At least one occurrence has been reported on the side of a county road on the Buffalo Gap National Grassland (Kostel personal communication 2006). The Dakota Minnesota and Eastern Railroad, which will traverse part of the Buffalo Gap National Grassland, could affect some *Eriogonum visheri* occurrences (USDA Forest Service 2003b). The draft environmental impact statement for the project predicts that, "there will be indirect impacts [on some Forest Service sensitive species] related to increased human population and increased use in the area" (USDA Forest Service 2003b).

Resource extraction

Various resource extraction activities occur within *Eriogonum visheri* habitat throughout its range. Much of the range of *E. visheri* lies in the hydrocarbon-rich Williston Basin (see Distribution and abundance section). The Williston Basin, a large structural basin known for its petroleum resources, lies underneath much of western North Dakota, eastern Montana, and northwestern South Dakota (Vaculik 2001). Of the seven counties in which *E. visheri* occurs in North Dakota, five (Billings, Golden Valley, McKenzie, Mountrail, and Slope) are oil-producing counties (North Dakota Petroleum Council 2004). Oil and/or natural gas are found in Carter County, Montana and have been located in all the counties in which *E. visheri* grows in South Dakota.

Oil and natural gas development and exploration take a substantial toll on habitat integrity and often lead to habitat degradation (Fiori and Zalba1 2003, Finn et al. 2005, Pembina Institute 2006). Habitat degradation and loss are caused not only by well pad construction but also by construction of associated pipelines, power lines, buildings and holding tanks, roads, temporary material storage sites, and, especially, an increase in incidental impacts such as informal two-track roads and vehicle turn-sites. Historically, well pads have been placed on valley bottoms, which is likely to have affected some *Eriogonum visheri* occurrences. The impacts of oil and gas developments on the hydrology of *E. visheri* habitat have not been documented. The energy bills proposed in 2005 provide tax breaks and incentives to encourage domestic oil and natural gas production (United States House of Representatives 2005, United States Senate 2005). As energy sources continue to be developed, more aggressive exploration and narrower well spacing are likely to the increase pressures on *E. visheri* habitat.

Threats from resource extraction are not distributed evenly throughout the range of *Eriogonum visheri*. In contrast to the intense activity in the Williston Basin, there is little potential for large-scale oil and gas development projects within the southern and southeastern parts of the range of *E. visheri*, including the Buffalo Gap National Grassland. This situation could conceivably change in the future since South Dakota is alleged to be an untapped resource for oil and gas reserves (McGillivray 2005).

Hard rock mineral development has also been common within *Eriogonum visheri* habitat. Commercially valuable commodities include lignite coal, bentonite, gravel, coal, and potash. Minerals tend to be most abundant in North Dakota. Uranium was once mined in northwestern South Dakota, but the deposits are generally not thick enough to support commercial mining operations (Woodard 2004). *Eriogonum visheri* occurrences have been found near gravel and scoria operations on the Little Missouri National Grassland 1 (Lenz 1993). Scoria is commonly quarried as an aggregate for unpaved road surfaces in northwestern South Dakota (Woodard 2004). Since this lightweight material breaks down quickly, it appears that this is a resource that will be excavated until sources are depleted. Coal mining is common in some parts of *E. visheri*'s range, but several mines are now abandoned. The coalmine at SD - 26 (**Table 1**) was apparently abandoned in 1952 and is unlikely to be re-opened (Ode 1987). Currently, resource extraction activities are not perceived to be a sizable threat in Region 2.

Soil disturbance

In general, all activities that lead to substantial soil disturbance are potential threats to *Eriogonum visheri*. Substantial disturbance alters soil structure, which is probably important to a species that has evolved to colonize a substrate with specific and unique properties (see Habitat and Demography sections). Although no information is available specifically for *E. visheri*, seeds in arid soils are generally distributed near the ground surface and seeds more than 7 cm below the surface are considered lost from the seed bank (Kemp 1989). Undue disturbance of the seed bank would be particularly detrimental because it is probably critical to the survival of this species (see Demography and Community ecology sections). Disturbance also accelerates natural soil erosion and changes or eliminates the microbiotic community (Ladyman and Muldavin 1996, Belnap et al. 2001). Disturbance and the trails created by motorized vehicles and livestock may also disrupt low energy water and sediment movement, which are probably involved in *E. visheri* seed dispersal and habitat maintenance.

Eriogonum visheri may tolerate some disturbance of anthropogenic origin, but the impact will be critically dependent upon the condition of the seed bank, the condition of *E. visheri* populations that can act as a seed source near the disturbed area, the residual edaphic conditions, and the invasion by non-native weedy plant species. The seed bank condition refers to the proportion of *E. visheri* seeds in relation to other invasive or weedy species as well as seed position with respect to germination requirement and soil structure. Disturbance affects soil structure, and there is currently no information as to what conditions *E. visheri* needs. With this type of habitat specialist, any loss of soil structure and properties may be very detrimental to long-term sustainability.

Recreation

Threats associated with recreation are not documented. Recreational off-road vehicle traffic and all-terrain vehicles (ATVs) have gained popularity within the last decade (e.g., ATV Source 1999-2004, OffRoadDirectory.net 2004). Badlands are popular destinations for mechanized vehicle recreation, and many areas are under heavy pressure for unrestricted use from off-road vehicle enthusiasts (ATV Source 1999-2004, Grant and Gorman 2004). Motorized vehicles can severely disturb vegetation, cause accelerated soil erosion, increase soil compaction, and add to pollution (Ryerson et al. 1977, Keddy et al. 1979, Aasheim 1980, Belnap 2002, Misak et al. 2002, Gelbard and Harrison 2003, Durbin et al. 2004). Because of the severe degradation caused by motorized vehicles, travel has been restricted to existing roads and trails on the Little Missouri, Grand River, and Cedar River national grasslands within Region 1 since July 2001 (USDA Forest Service 2001b). *Eriogonum visheri* occurrences within 300 ft. (92 m) of roads and trails may still be impacted because campsites within that distance of a road can still be used (USDA Forest Service 2001a).

Livestock grazing

Livestock grazing is a principal industry throughout the range of *Eriogonum visheri*. The majority if not all of the occurrences on the national grasslands in both Regions 1 and 2 are apparently within grazing allotments (**Table 1**, **Table 2**). However, the habitat of *E. visheri* is unlikely to be preferentially used by livestock since they are most likely to pass through the barren badland habitats of *E. visheri* in search of more abundant forage. Nevertheless, livestock have been reported to trample and browse plants, and cattle trails are frequent throughout this taxon's habitat (**Table 1**, **Table 2**; Schmoller 1993, Diller 2002). Therefore, although the paucity of *E. visheri* plants makes it unsuitable as an adequate source of feed for livestock, cattle may still graze on *E. visheri* plants, leading to impacts on flower or seed production. *Eriogonum visheri* plants along the cattle trails may be most vulnerable to livestock herbivory. It was noticed that *E. gypsophilum* (gypsum buckwheat) plants that grew along cattle trails appeared to be the most frequently browsed, presumably by livestock (Spellenberg personal communication 2005). *Eriogonum gypsophilum* is a rare perennial endemic to barren and semi-barren gypsum outcrops in New Mexico.

Herbivory and direct trampling are not the only consequences of livestock grazing. Livestock contribute to soil disturbance, soil compaction, and localized changes of soil properties such as increases in nitrogen and other minerals (Fleischner 1994). Heavy stocking rates will particularly degrade sites (Montana Natural Heritage Program 1997-2005). Livestock also contribute to the spread of non-native weed plant species (Sheley and Petroff 1999). On the Buffalo Gap National Grassland, permits have been issued for bison grazing (USDA Forest Service 2001a), but details regarding bison use of *Eriogonum visheri* habitat are not available.

Invasive vascular plant species

The observations that *Eriogonum visheri* grows where other vegetation is sparse suggest that it may not be able to compete with aggressive, fast growing species (see Community ecology section). A comment was made for ND - 36 (**Table 2**) that the reason fewer plants were observed there than previously could be because of the development of lush grassland and that the habitat was succumbing to natural succession (Diller 2002). This might be true, but the naturalness of the present grassland successional processes in much of the Dakotas is debatable. Anthropogenic influences have substantially modified vegetation composition throughout North and South Dakota since before the 1800's (Johnson 1982) and even since the early 1900's (Visher 1912). Cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum*), and intermediate wheatgrass (*A. intermedium*) are all non-native grasses that are now common in the Dakotas. Many areas have been seeded with non-native grasses (e.g., crested wheatgrass at ND - 14 [**Table 2**]), and this is obviously not a "natural" event. Visher (1914) noted that fields (presumably he specifically meant cropland) in Harding County in 1914 were frequently almost "perfectly free from weeds" and went on to comment that, "weeds were not troublesome … mainly due to dryness." One hundred years later, weeds are recognized as being a severe problem for the economy in both North and South Dakota (Lym 2004, South Dakota Department of Agriculture 2005). Effective control methods are currently being evaluated on the Dakota Prairie Grasslands (USDA Forest Service 2005b) and the Buffalo Gap National Grassland (USDA Forest Service 2001a), but the problems caused by invasive weeds generally are very difficult to solve.

Leafy spurge (*Euphorbia esula*) was observed in a roadside ditch near ND - 23 (**Table 2**). Other than this observation, there are no data to indicate an imminent invasion of noxious weeds at any of the known *Eriogonum visheri* occurrences (Lym 2004, South Dakota Department of Agriculture 2005). However, other aggressive and invasive plant species such as sweetclover (*Melilotis officinalis*), tumbleweed (*Salsola iberica*), and kochia (*Kochia scoparia*) are common at many occurrence sites (**Table 1**, **Table 2**). The magnitude of the potential threat that they pose to the *E. visheri* occurrences is not determined. Herbicides used to kill dicot (forb) weed species are likely equally lethal to *E. visheri* (Boutin et al 2004). Drift from herbicides used in highway right-of-way maintenance may pose a threat to occurrences near highways and roads.

Habitat modification, rather than direct competition, is another consequence of non-native plant invasions. Non-native plant species are likely to be significant agents of modification to unoccupied *Eriogonum visheri* habitat making it unavailable for colonization. Some weed species, such as knapweeds, produce allelopathic chemicals that essentially poison the soil to reduce competitors, and other weeds, such as cheatgrass, can alter the fire frequency at a site (D'Antonio and Vitousek 1992, Sheley and Petroff 1999, Inderjit 2005).

Pollinators

Arthropod species may be important to *Eriogonum visheri* either as pollinators or as partners in a mutualistic relationship. The importance of arthropods to the long-term sustainability of *E. visheri* is not known (see Community ecology section). There is no indication that *E. visheri* relies on specialist pollinators or even to what extent cross-pollination is essential for the maintenance of its genetic diversity. Arthropod assemblage and abundance are vulnerable to pesticide spraying, habitat fragmentation, and reduced abundance of plant species that provide alternative sources of pollen and nectar (Bond 1995, Kearns et al. 1998). The level of risk imposed by loss of specific species or disruption of pollinator activity currently cannot be estimated.

Fire

The importance of fire to the life cycle of *Eriogonum visheri* is not known. The low fuel loads of the badlands suggest that *E. visheri* habitat was historically and is currently only infrequently exposed to fire occurrence. However, the lignite coal seams of the badlands apparently do catch fire after lightning strikes, and if left alone underground, these fires have been documented to burn for decades in North Dakota (Beechie 2004). Since 1999, at least four grass fires have been attributed to burning coal seams (Beechie 2004). The consequence of fire suppression and of fire itself on the *E. visheri* life cycle needs further evaluation.

Environmental stochasticity

Environmental stochasticities pose potential threats to *Eriogonum visheri*. The term stochasticity can be thought of as meaning uncertainty (Frankel et al. 1995). Environmental stochasticity arises from the random, unpredictable changes in weather patterns or in biotic members of the community (Frankel et al. 1995). Environmental stochasticities that probably affect the survival and reproductive success of *E. visheri* include variations in temperature and precipitation, accelerated soil erosion and variable populations of wildlife. There are two aspects to environmental stochasticity: the absolute values of a variable (e.g., total rainfall) and the seasonal timing of a variable (e.g., when precipitation or maximum and minimum temperatures occur). While both may have considerable effects on the long-term sustainability of *E. visheri* populations, the latter is likely to have a substantial effect on the life cycle of *E. visheri*. For example, periods of drought in the springtime may delay and/or reduce seed germination and plant establishment whereas an early frost at the end of summer might reduce the amount of viable seed produced by curtailing the maturation process.

Another element of environmental stochasticity is climate change. There are many possible effects of climate change on this particular species. Since *Eriogonum visheri* appears to be adapted to unstable weather patterns, it may fare relatively well in a changing climate. Over the last century, the average temperature in Pierre, South Dakota, has increased 1.6 °F (0.9 °C), and precipitation has increased by approximately 5 to 10 percent in western parts of the state (U.S. Environmental Protection Agency 1998a). During the same time period, although the average temperature near Bismarck, North Dakota, has increased by a similar amount, 1.3 °F (0.7 °C), precipitation has decreased by up to 10 percent (U.S. Environmental Protection Agency 1998b). Based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), by 2100, temperatures in North and South Dakota could increase by 3 °F (1.7 °C) in summer and up to 4 °F (2.2 °C) in other seasons (Johns et al. 1997, U.S. Environmental Protection Agency 1998a, 1998b). In South Dakota, the same HadCM2 model predicts that precipitation will increase by approximately 10 percent in spring, summer, and fall, and approximately 20 percent in winter (U.S. Environmental Protection Agency 1998a). In North Dakota, despite the recent below average amounts of rainfall, precipitation is also predicted to increase by approximately 5 percent in spring, approximately 10 percent in summer, approximately 15 percent in fall, and approximately 25 percent in winter (U.S. Environmental Protection Agency 1998b).

Other climate models may show different results. Four of the five most widely used General Circulation Models indicate that the future climate in North Dakota, South Dakota and eastern Montana is likely to include higher average temperatures, increasing winter precipitation, declining summer precipitation, a decrease in soil moisture, and an increase in the frequency and severity of drought (USGS Biological Resources Division. 2004). More information on the consequences of climate change can be found in Christy (2000), Alley (2002), Pew Center (2005), New Zealand Climate Change Office (2006), U.S. Global Change Research Program (2006). The majority opinion within the scientific community is that climate change will cause weather to become more extreme (U.S. Global Change Research Program 2005). That is, the amount of precipitation on extreme wet or snowy days is likely to increase and the frequency of extreme hot days in summer will increase because of the general warming trend. Increased periods of drought are likely to be detrimental to *Eriogonum visheri*, whereas more violent storms may disrupt seed dispersal and seedling establishment. However, much more information is needed before any accurate predictions can be made as to the response of *E. visheri* to potential environmental changes.

Genetic and demographic stochasticities

Intrinsic or biological uncertainties also contribute to a species' vulnerability. These uncertainties include elements of genetic and demographic stochasticity and may only be avoided by maintaining an adequate number of populations that are composed of sufficiently genetically unique individuals as to maintain a necessary level of genetic diversity. However, neither of these quantitative parameters has been studied for *Eriogonum visheri*.

Genetic stochasticities are associated with random changes, such as inbreeding and founder effects, in the genetic structure of populations (see Reproductive biology and autecology section). The consequences of inbreeding depression may become a significant threat if populations experience significant declines in size and number due to habitat loss, direct destruction, or attrition due to poor reproductive output (Soulé 1987). If self-pollination has become obligatory due to extrinsic forces like habitat fragmentation or pollinator decline and if outcrosssing is evolutionarily the ideal reproductive strategy, there may be significant inbreeding depression among small, dispersed groups of plants (Neel et al. 2001). Loss of genetic variation can reduce the ability of populations to adapt to changing environments and pest and disease pressures (Barrett and Kohn 1991, Quammen 1996). The potential magnitude of the threat from inbreeding depression on reducing *Eriogonum visheri* fitness to a changing environment is unknown.

Inbreeding is not always detrimental in small populations. Inbreeding can purge deleterious recessive mutations, thereby avoiding inbreeding depression (Byers and Waller 1999). Life history traits appear to influence the extent of purging; annuals are more likely to exhibit purging than perennial plants (Byers and Waller 1999). Evidence also suggests that purging depends upon a wide range of factors and that it is an inconsistent force within populations (Byers and Waller 1999).

Demographic stochasticity relates to the random variation in survival and fecundity of individuals within a fixed population (Quammen 1996). Demographic stochasticity is likely to be particularly important for annual species with highly variable birth and death rates. Where occurrences are small, perhaps fewer than 50 individuals, demographic uncertainties may well become especially significant (Pollard 1966, Keiding 1975). Chance events independent of the environment may affect the reproductive success and survival of individuals that, in very small populations, have an important influence on the survival of the whole population. For example, seeds may be aborted by a certain percentage of the population, the percentage becoming larger and perhaps reaching 100 percent as the population size becomes smaller. Some *Eriogonum visheri* occurrences are very small, particularly in some years, and an individual plant may be relatively important to the long-term survival of the species in that area.

Malentities envirogram

Malentities and potential threats that apply to any of the known *Eriogonum visheri* occurrences are outlined in the envirogram in **Figure 8**. Threats to specific occurrences on land managed by Region 2 appear to be relatively low at the current time. Other than livestock grazing, there appears to be little anthropogenic activity at known occurrences.

Conservation Status of Eriogonum visheri in Region 2

Eriogonum visheri is designated a sensitive species in Region 2, where it grows on land managed by the Buffalo Gap National Grassland. Land exchanges between USFS and private landholders in the 1990's removed some occurrences formerly on the Buffalo Gap National Grassland from public ownership (Linabery and Isaacs 1992). This suggests that the distribution and abundance of *E. visheri* has declined in Region 2 since the land exchanges were made. There is no information on how many occurrences might have been gained through land exchanges.

Within the range of *Eriogonum visheri*, occurrences in Region 2 appear to be some of the least affected by human threats. Resource extraction activity is currently negligible, and most *E. visheri* occurrences on the Buffalo Gap National Grassland do not appear to be exposed to high levels of either livestock grazing or destructive recreational activity.

Surveys for *Eriogonum visheri* have been made periodically on the Buffalo Gap National Grassland over the last two decades. However, due to the sporadic nature of the data collection, trends in populations cannot be determined. The problem of estimating abundance trends without annual monitoring data is compounded by the naturally variable temporal as well as spatial abundance of the species. Because its abundance appears strongly affected by environmental conditions, influences of other factors, such as habitat modification, are difficult to detect (see Distribution and abundance and Population trend sections).

The Nebraska National Forest is composed of two national forests and three national grasslands, including the Buffalo Gap National Grassland. The Nebraska National Forest Management Plan was recently revised and is incorporated within the Northern Great Plains Management Plan (USDA Forest Service 2001a). The biological assessment and evaluation in this management plan specifically included *Eriogonum visheri* (USDA Forest Service 2004). Eight conservation measures provide management objectives, standards, and guidelines for this species:[4]

1) Prioritize the species for preparation of a conservation strategy (Objective)

2) Conduct target surveys for the species (Objective)

3) Manage vegetation so native forbs periodically complete their full reproductive cycle (Standard, Guideline)

4) Do not authorize new developments or placement of salt or minerals in occupied habitat (Guideline)

5) Prioritize occupied habitat for noxious weed control using methods that do not pose adverse risks to Dakota buckwheat [*E. visheri*] (Guideline)

6) Design timing, intensity and frequency of mowing, burning, and livestock grazing to benefit Dakota buckwheat [*E. visheri*] (Standard)

7) Require permits to collect sensitive plants or parts of sensitive plant species (Standard)

8) Prioritize nearby lands with important or unique habitat for threatened, endangered, and sensitive species habitat for acquisition (Guideline).

A conservation strategy has not yet been prepared for *Eriogonum visheri* in Region 2 (Sargent personal communication 2006). Currently, there are no plans for systematic targeted surveys or monitoring for *E. visheri* on the Buffalo Gap National Grassland (Sargent personal communication 2005, 2006). A graduate student surveyed the flora of the Wall Ranger District of the Buffalo National Grassland during the summers of 2004 and 2005 and found four vigorous but small *E. visheri* occurrences (Sargent personal communication 2005, Kostel personal communication 2006). Apparently, the perceived abundance of *E. visheri* has lowered its priority for the development of a species-specific conservation strategy and for its being the object of targeted surveys. No defined

[4]Verbatim from Conservation Measures and Mitigation, Alternative 3 (accepted alternative) Appendix H in Northern Great Plains Management Plan (USDA Forest Service 2001).

programs for invasive plant species control have been undertaken in *E. visheri* habitat (Sargent personal communication 2006).

Management of Eriogonum visheri in Region 2

Implications and potential conservation elements

Twenty-two of the 77 known occurrences of *Eriogonum visheri* in South Dakota occur on National Forest System lands managed by Region 2 (**Table 1**). Six of the remaining occurrences in South Dakota are on lands administered by Region 1. Twenty-five of the 42 occurrences outside South Dakota are on National Forest System lands administered by Region 1 (**Table 2**).

The total numbers of individual plants for all sites, and therefore, the proportion of the total number within Region 2 boundaries, is unknown. It is apparent that much of the management of this species' habitat lies outside of Region 2. However, Region 2 is in a position to contribute significantly to the overall conservation of the species. Threats to the species, especially from mineral extraction activities, are minimal in Region 2 compared to those in surrounding areas. Special status designation or other conservation efforts for several sites in Region 2 would benefit an important portion of the species and contribute to the overall species viability. Since the conservation status of occurrences outside National Forest System jurisdiction is largely unknown and unpredictable, management of the occurrences on USFS lands may be critical for the persistence of the species. Edaphic endemic populations have scientific and conservation significance. Conserving as many geographically separated populations as possible in order to maximize the conservation of genetic variability may be very important for this taxon.

A lack of commercially important natural resources on land managed by Region 2 affords some level of protection to *Eriogonum visheri* occurrences from many impacts of anthropogenic origin that are common elsewhere in its range. The establishment of a non-motorized recreation area on the Buffalo Gap National Grassland also protects at least one occurrence from particularly destructive recreational activities (see Management section). Designating additional areas on the Buffalo Gap National Grassland where *E. visheri* would be protected from anthropogenic activities and invasive weeds may have particularly high conservation value in maintaining genetic diversity of the species. This is because several of the areas that could be chosen for protection are relatively far apart and have large and vigorous occurrences. Protected *E. visheri* sites on National Forest System land in Region 2 would also be less likely to experience habitat fragmentation and accelerated habitat modification, which are likely to occur in many other parts of its range.

Sensitive species status

Maintaining *Eriogonum visheri* as a USFS sensitive species ensures that the taxon is considered during management planning and encourages periodic evaluation of its status on National Forest System land. USFS rules dictate that a biological evaluation be made before any significant project be undertaken in sensitive species habitat (see Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies section). A biological evaluation is a "documented Forest Service review of activities in sufficient detail to determine how an action may affect sensitive species" (USDA Forest Service 2003a). The significance of potential adverse effects on the population or its habitat within the area of concern and on the species as a whole must be analyzed by the line officer (Pivorunas 2005). Approved impacts may result in loss of individuals, but according to Forest Service Manual 2670.32, the decision to allow impacts on occurrences of sensitive species "must not result in loss of species viability or create significant trends toward Federal listing" (Pivorunas 2005).

Abundance and trends

At least 12 occurrences formerly under USFS jurisdiction in Region 2 are now on private land (**Table 1**). These occurrences no longer have any protection and will not undergo biological evaluations to assess the consequences of land use practices in the future. It is unknown if these occurrences now on private land have been lost or remain viable. Even if the occurrences were lost, it cannot be known with certainty whether the loss affects the viability of the species, since the extent of the potential loss of genetic variability, the potential loss of the seed bank, and the potential loss of habitat are unknown.

An important issue that relates to management of *Eriogonum visheri* is its variable occurrence size. A small population might be sacrificed due to the perception that only a few plants with possibly limited genetic value will be impacted. However, a small population one year may not reflect the potential of the occurrence in future years and its demise may represent the loss of a large seed bank. In addition, the genetic conservation value of populations may be unrelated to size. A larger population is not necessarily a more genetically valuable population (Karron et al. 1988). The genetic value of a small population may be underestimated. For example, alleles that were absent in larger populations were only found in a small population of a rare *Astragalus* species (Karron et al. 1988). Therefore, without molecular data on genetic structure, it is important to conserve as many geographically separated populations as possible in order to maximize the conservation of genetic variability.

Habitat loss

Potential habitat of *Eriogonum visheri* has not been described. Quantitative estimates suggest that this taxon occupies as little as 0.5 percent of its apparently suitable habitat. For example, in 1993, approximately 961 acres of apparently suitable habitat were surveyed on the Buffalo Gap National Grassland, but the area occupied by *E. visheri* was estimated to be only 4.84 acres (Schmoller 1993). Currently, it appears likely that if all of those 4.84 acres were lost to habitat modification, *E. visheri* would be able to colonize other areas. However, the total acreage that could be successfully colonized is unknown. Until potential habitat is accurately known, the degree of "habitat loss" that can be tolerated is difficult to estimate.

Sensitive Species Management Guidelines in Northern Great Plains Management Plan

Most of the USFS guidelines for sensitive species apply to both perennial and annual life forms. However, each guideline needs to be carefully considered on a taxon-specific basis. For example, one of the guidelines for sensitive species management in the 2001 Northern Great Plains Management Plan (see Conservation Status of *Eriogonum visheri* in Region 2 section) indicates that only occupied habitat will be considered (e.g., "Do not authorize new developments or placement of salt or minerals in <u>occupied habitat</u>"). Occupied habitat is very difficult to define for a species where a large proportion of its population may reside in the seed bank. Biological evaluations that concentrate on areas occupied by plant stems may miss areas occupied by dormant seeds. The seed bank is probably very important in maintaining sustainable populations of *E. visheri*, but this facet of its life history and biology makes it vulnerable to unintended disturbance. This situation is not unique to *E. visheri* and poses a problem in achieving adequate conservation of any plant species with similar life history characteristics.

Land use – livestock grazing, natural resource development and recreation

The past and present primary land uses of *Eriogonum visheri* habitat are livestock grazing and resource extraction. The latter has been limited on the Buffalo Gap National Grassland in Region 2. Unlike other parts of its range, the Buffalo Gap National Grassland is not rich in either saleable mineral materials (e.g., gravel, sand, stone, clay, petrified wood) or locatable minerals, which are hard rock minerals that are mined and processed for the recovery of metals (USDA Forest Service 2001a). Nevertheless, although most gravel pits occur on private lands, several gravel pits have been developed on the Buffalo Gap National Grassland for the purpose of county road improvements, and *E. visheri* occurrences can be considered likely to occur at such sites in the future (USDA Forest Service 2001a). Currently, no mining for locatable minerals occurs on any part of the Nebraska National Forest (USDA Forest Service 2001a).

Similarly, leasable minerals, which include oil and natural gas, do not appear to be abundant on the Buffalo Gap National Grassland, which is located just south of the Williston Basin (see Distribution and abundance and Threats sections). All Nebraska National Forest land, except for the Soldier Creek Wilderness and Pine Ridge National Recreation Area, is available for leasing after the USFS has completed required National Environmental Policy Act analysis (USDA Forest Service 2001a). However, the only significant oil production has been in the western half of the Buffalo Gap National Grassland in Fall River County (USDA Forest Service 2004). No natural gas is produced on the Buffalo Gap National Grassland (USDA Forest Service 2004). Three oil wells on the Buffalo Gap National Grassland have produced oil since the early 1980's (USDA Forest Service 2001a). Currently, the number of barrels of oil produced per day is quite low as the fields are nearly drained (USDA Forest Service 2001a). Even though no new fields have been discovered since the 1980's, and all of the 10 wildcat wells that have been drilled since 1995 were dry, some exploration is still occurring on the national grassland (USDA Forest Service 2001a). In addition, South Dakota is perceived as being an untapped resource for oil and gas reserves, and more exploration is quite likely (McGillivray 2005).

All areas in which *Eriogonum visheri* grows on the Buffalo Gap National Grassland are open to domestic livestock grazing. The long-term impacts of grazing on *E. visheri* populations are unknown. Ode

(1987) suggested examining grazing impacts using livestock exclosures. To date, no such studies have been conducted. These studies would not be easy to carry out because the condition of the seed banks as well as existing plants would need to be considered. The exclosures would need to be large enough and positioned in such a way as to prevent the loss of seeds. One can envision a study whereby exclosures could be positioned so that plants within the exclosures would act as a seed source for areas outside the exclosures.

Recreation pressures, including off-road vehicle traffic, may become more significant as the human population increases in areas within easy access of *Eriogonum visheri* habitat (see Threats section). Currently, a small part of *E. visheri* range on the Buffalo Gap National Grassland has been placed off-limits to motorized vehicles (USDA Forest Service 2002). This management unit, named the Rake Creek backcountry non-motorized area, carries the designation Management Area (MA) 1.31 in the current management plan. In MA 1.31 areas, oil and gas leasing is allowed, but no surface occupancy is permitted. This means that the mineral estate may only be accessed from adjacent areas. Road construction for geophysical activities is prohibited, but off-road geophysical access is allowed. If this is not feasible, portable techniques must be used (USDA Forest Service 2002). Livestock grazing continues in this area. A proposal to further limit motorized travel on National Forest System land is being considered (USDA Forest Service 2004).

Tools and practices

Baseline inventory data have been collected for *Eriogonum visheri* on the Buffalo Gap National Grassland (see Distribution and abundance section). Creating a comprehensive inventory of a taxon assists in evaluating its vulnerability to local extirpations. However, long-term monitoring of occurrences is the only way to determine trends in a taxon's abundance and range. No monitoring programs have been established for *E. visheri* in Region 2. Monitoring occurrences in areas before and after new management practices have been implemented is an ideal way to evaluate the benefits of any changes in management practices. Long term (two decades or more), non-project related monitoring of *E. visheri* occurrences would be valuable in determining the spatial dynamics and the natural temporal variability in population size.

Species inventory

Range-wide, inventory activity has been irregular over the last two decades. In the 1980's and again in the mid-1990's, several inventories helped to clarify the range of *Eriogonum visheri* in Regions 1 and 2 (Ode 1987, Ode 1988, Linabery 1991, Linabery and Isaacs 1992, Lenz 1993, Schmoller 1993, Vanderpool 1993). On the Buffalo Gap National Grassland, surveys for *E. visheri* were made in 1983, 1986 (Ode 1987), 1991 (Linabery 1991), 1993 (Schmoller 1993), and 1995 (South Dakota Natural Heritage Program 2005). Surveys in North Dakota (Region 1) occurred in 2001, 2002, and 2003 (Diller 2002, North Dakota Natural Heritage Inventory 2003). In conjunction with aboveground censuses, studies on the *E. visheri* seed bank size and persistence would be valuable in understanding the strengths and vulnerabilities of the taxon (e.g., Alexander and Schrag 2003, Adams et al. 2005). Inventory records that include the numbers of individuals, the area they occupy, their spatial distribution within potential (apparently suitable) habitat, and the extent of unoccupied potential habitat are useful for future comparisons. Life stage at the time of the survey and details of the habitat also provide important information for comparative studies within and between years. Specific geographic information on where plants occur provides the means for relocating occurrences precisely. With the advent of low cost global positioning system (GPS) receivers, this information is relatively easy to obtain. *Eriogonum visheri* populations are likely to be spatially dynamic, and occurrence boundaries may need to be extended instead of increasing the number of occurrences if populations shift over time. Inventories need to be conducted when the plants are flowering. Field observations of flower color, pubescence, overall size, and habit are particularly useful characteristics to record (Reveal 2005b). Flower color can change after a specimen is pressed and mounted. Reveal (2005b) indicated that it is important to include leaves, fruits, and ample flowers when collecting specimens of annual *Eriogonum* species.

In surveys of *Eriogonum visheri*, one omission appears to have been in verifying that estimated counts represent true counts. In many cases, the colonies occupy relatively small areas (Schmoller 1993); therefore, estimates can be compared and verified relatively easily with direct counts. For example, several areas could be delineated with pin flags, and each field technician could independently first estimate and then count the numbers of individuals within the given area. This effort would serve two purposes. First, the estimate could be checked against direct counts for each individual technician, and secondly, the field technicians would determine how consistent with each other their estimates and counts are. Inter- and intra-operator sampling variability measurements are important for analyses of trends. The methods used during the survey to make estimates of the numbers of individual plants are also important to document so that they can be evaluated in the future. Estimates of population size derived from maximum and minimum numbers of plants per square meter must take into account the spatial heterogeneity of its distribution. The numbers of plants per square meter cannot simply be scaled-up to estimate the numbers per hectare without careful consideration of the spatial pattern of colonies as well as the heterogeneity of habitat.

In 1993, approximately 961 acres were surveyed on the Buffalo Gap National Grassland, but the area occupied by *Eriogonum visheri* was estimated to be only 4.84 acres (Schmoller 1993). The number of plants within the survey areas was estimated to total 71,024. This estimate was apparently derived from counting plants in 10 areas and by counting plants along a transect line using a variable (14 to 41) number of plot frames in each of four other locations. It is not clear if the number of plot frames was limited by the area occupied or by the area of apparently suitable habitat. Within the area of interest, transects utilizing plot frames need to run over habitat that appears suitable but unoccupied as well as that occupied, otherwise an over-estimate of the extrapolated abundance will result. In addition, interpretation of the numbers of plants in an area can be highly erroneous due to the use of extrapolations. As mentioned above, the 1993 survey estimated a total of 71,024 plants occupying an area of 4.84 acres, equaling 1.96 hectares (Schmoller 1993). However, the study's author considered the density of individuals on a per-meter-square basis and concluded that, "In terms of hectares this is a range of 1,176 to 3,000,000 plants per hectare. The average is 158,693. In terms of acres, this is a range of 476 to 1,214,100 with an average of 64,223" (Schmoller 1993). The validity of portraying the data in this manner is dubious. In the 961 acres surveyed, 71,024 individuals were found, indicating that there were only 74 individuals per acre (183 individuals per hectare). If only occupied habitat is considered, the density would increase to 14,674 individuals per acre (36,211 per hectare). Neither of these estimates agrees with the conclusions of the author that there is an average of 64,223 plants per acre. These types of discrepancies in estimates of numbers of plants need to be reviewed carefully when assessing the abundance and trends of a taxon.

Habitat inventory

The characteristics that identify potential *Eriogonum visheri* habitat have not yet been rigorously defined, and predictive habitat models have yet to be developed (Dingman 2004). Currently, potential habitat can only be generally described as unoccupied habitat that appears to be similar to occupied sites. Not all areas that appear suitable for colonization are occupied. Consequently, reports detailing the conditions where plants do not occur can be as important as descriptions of where they do occur. Indicating the proportion of habitat that is occupied during a survey may also be very helpful in understanding the spatial pattern of the occurrence (Ode 1987).

Until systematic studies determine what constitutes potential habitat (that which can be colonized), estimates of the area of potential habitat within the badlands are likely to be highly inaccurate. One element of unsuitable habitat that is reasonably well-documented is a high cover by grasses or weedy forbs.

Suitable and unsuitable habitat for *Eriogonum visheri* colonization may change according to environmental conditions. In some years, the amount of rainfall, temperature regime, or some other parameter may permit colonization of areas that could not sustain plants under other conditions. The potential dynamics of available habitat is an important consideration when estimating the impacts of habitat loss within the species' range.

The consequences of long-term climate change are unknown but may influence the amount of habitat available for *Eriogonum visheri* colonization. The possible temporal and spatial variation in the amount of available suitable habitat may be important factors in influencing the future of *E. visheri*. Where substantial changes in the spatial distribution of suitable habitat occur, the fate of *E. visheri* may depend on characteristics of its biology. For example, seed dispersal characteristics are likely to be intimately associated with determining whether *E. visheri* can actually colonize unoccupied habitat.

Population monitoring

Although several areas in which (sub)occurrences have been found have been visited more than once, and some have been visited multiple times over successive years, it is often unclear whether the same occurrence has been revisited or whether the occurrence was only approximately relocated within the same general area. In many instances, the latter case appears to be most likely (Linabery and Isaacs 1992, Schmoller 1993, Vanderpool 1993, Diller 2002). The increasing availability and use of inexpensive and accurate GPS technology can be expected to prevent this from being a problem in the future. Currently, there is no way to judge the spatial dynamics of *Eriogonum visheri*, which may be very important when considering management alternatives. Permanent plots are valuable for collecting specific demographic data, but because this taxon's occurrences are both temporally and spatially dynamic, there is a high probability that problems associated with autocorrelation will arise (Goldsmith 1991). Fixed plot designs tend to fail to reveal boundary changes. A transect that encompasses both occupied and unoccupied suitable habitat in the year it is established would be more likely be able to detect changes that a fixed plot design would miss (Goldsmith 1991, Elzinga et al. 1998, Elzinga et al. 2001). The monitoring protocol also needs to take into account that seeds could be washed considerable distances and that they may remain dormant for several years.

Counting the number of *Eriogonum visheri* individuals or recording their cover in relocatable quadrats along a transect line can be employed. However, even though the latter alternative may be quicker, a drawback is that cover may not reflect the number of individuals, and thus cannot be used as a measure of population size. The amount of cover reflects size as well as number of individuals and depends on local habitat conditions as well as annual fluctuations in weather patterns. Therefore, it is important to evaluate the ramifications of recording cover to assess *E. visheri* status and trends before the monitoring project is initiated.

Measurements of population size are important because current understanding suggests that populations with the highest numbers of individuals are most robust against stochasticity. Frequency measurements, which are the presence or absence of individuals, in plots or quadrants within a given area are often used to monitor occurrences (Goldsmith 1991, Elzinga et al. 1998, Elzinga et al. 2001). An advantage is that the method is sensitive to spatial changes within the occurrence (Elzinga et al. 1998). A serious disadvantage is that the density and actual numbers of individuals are not recorded (only present or non-present), and therefore changes can be difficult to interpret biologically (Elzinga et al. 1998). For example, an increase in frequency may reflect an occurrence that is covering a larger area but also one that has experienced a precipitous decline in density and the actual numbers of individuals in the occurrence may have been significantly reduced. Thus, the potential vulnerability to extirpation cannot be accurately evaluated.

When the biology and ecology of this species are better understood, there may be parameters other than a measure of abundance or the occupied area upon which to evaluate sustainability. The monitoring design can be adjusted accordingly. For example, Mehrhoff (1989) reported that stable populations of the rare orchid *Isotria medeoloides* contained a high proportion of flowering plants whereas declining populations contained only few. In this case, noting the proportion of reproductive individuals was very important in assessing long-term sustainability.

Monitoring is the best way to determine the effects of changing management practices or environmental conditions. The monitoring protocol needs to include the careful recording of habitat conditions. Changes in the target species are frequently reflected in the condition of the soils and associated species. In addition, incidental observations such as livestock stocking rate or the location of an existing pipeline installation may be useful in interpreting biological observations made several years after the activity or event is first noted. Where possible, current management practices or development projects need to be recorded even if there is no evidence of the activity at the time of the survey. A low conservation value has been placed on occurrences in high disturbance sites (Washington personal communication 2005). However, occurrences in anthropogenically disturbed areas are useful for studying the dynamics of weed invasion or how disturbance factors affect long-term occupation of the sites relative to undisturbed locations.

Appropriate monitoring frequency and overall duration are species specific. The length of time that occurrences are monitored needs to be sufficient to identify underlying trends in the presence of normal year-to-year variability. For some perennial species, observations once every three years or even less often may be sufficient. However, for an annual species such as *Eriogonum visheri*, annual monitoring is most appropriate until a statistically valid assessment of temporal variability can be made. The number of plots, area covered, and habitat details collected will depend upon the budget and resources available. The protocol needs to be sufficiently straightforward and the design robust enough so that operators with all levels of expertise can carry it out successfully. Another consideration in monitoring design is that the analyses need to account for different levels of search intensity in the event that funding changes between years. Appropriate statistical analyses need to be established prior to the first year of monitoring and take into account various budget-imposed circumstances such as different search intensities, numbers of occurrences that can be visited in any given years, and total area covered.

Establishing photo points and taking photographs are helpful in providing a visual record of site conditions. While photographs are very useful to augment and support surveys, they are not appropriate replacements for written descriptions of *Eriogonum visheri* plants and habitat conditions. Even though digital copies are convenient and easy to store, many museums and researchers suggest storing additional slides or even prints, as in 50 years time the technology to read current digital media may no longer be available.

Habitat monitoring

Habitat for *Eriogonum visheri* is generally understood to include barren and near-barren soils of particular geologic formations (see Habitat section). Although precise habitat requirements may not be known, the existing characterization of semi-barren and barren habitat might permit a limited degree of habitat monitoring in the absence of plants. Habitat monitoring in the absence of *E. visheri* is likely to be most effective if the goal is to detect changes in overall vegetation cover, weed density, or physical parameters such as soil erosion. Grass and invasive forb cover is an important factor in considering the quality of potential habitat.

The frequency with which colonization of isolated patches of potential habitat occurs is unknown. Occurrences appear to be spatially dynamic, but seed dispersal might be limited and plants may only slowly move into unoccupied habitat. On the other hand, seeds washed in a rainstorm may travel quite long distances away from the original colony. If plants are observed at a site, it is clear that the site is capable of supporting the taxon, and it can be monitored for changes that affect the colonies. Unfortunately, if habitat is not occupied at the start of the monitoring period, the effects of management decisions on colonization cannot be unequivocally evaluated. If unoccupied land becomes weedy or disturbed by livestock and is not colonized, it may have little to do with the weeds or the livestock *per se*, but may instead be a function of the original microsite characteristics or lack of seed dispersal.

Population or habitat management approaches

Common approaches to conserving a rare taxon include seed banking and designating known occurrences as protected areas.

Seed banking

Eriogonum visheri seed has been collected (from SD - 25 in **Table 1**) and sent to the Center for Plant Conservation (Locklear undated; see Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies section). The Center for Plant Conservation is dedicated to preventing the extinction of native plants in the United States and maintains many taxa as seed, rooted cuttings, or mature plants, depending upon the taxon's requirements. Banked seed could be important if restoration is necessary in the future. However, seed banking may have limited value for restoring taxa whose ecology is not understood. If microhabitat requirements are not known, the conditions to maintain an occurrence may not be met even if germination and seedling establishment are achieved. Therefore, re-establishing occurrences that have been extirpated may be a very difficult task.

Designated conservation areas

Common methods of protecting sensitive areas from anthropogenic threats include erecting fences, establishing barriers to ATV traffic, and/or posting signs indicating that the areas are closed. However, the success of signage and barriers in protecting areas vulnerable to disturbance varies among sites and with site users. Some *Eriogonum visheri* occurrences are in the Rake Creek backcountry non-motorized area on the Buffalo Gap National Grassland. Since this area is only open to non-motorized recreation, these occurrences are protected from the impacts of off-road vehicle traffic. *Eriogonum visheri* is not known to occur within any other areas that are currently afforded special protections from anthropogenic activities. Establishment of other special areas would help to ensure the persistence of *E. visheri*.

Information Needs

Relatively little is known about many aspects of the biology and ecology of *Eriogonum visheri*. Much more needs to be known about the species' population dynamics and its vulnerability to disturbances such as motorized vehicle traffic and livestock grazing. Seed bank characteristics need to be studied in order to determine the vulnerability of occurrences. Seed bank size and dynamics might be particularly important in explaining the extent of the temporal and spatial variability in abundance and for assessing the response and/or sensitivity of *E. visheri* to disturbance. Determination of seed longevity, seasonal mortality, and other components of minimum viable population size are also important factors in evaluating potential vulnerability (Menges 1991). These questions are a high priority since their answers will help determine appropriate management strategies. A study of the patch dynamics of an area in which *E. visheri* occurs may also reveal how occurrences relate to surrounding vegetation types and how disturbances affect distribution at the local level. However, it needs to be recognized that the temporal variability in population size may make it very difficult to evaluate different management strategies within a short time frame.

Lenz (1995) suggested that there is a correlation between environmental conditions, especially precipitation, and population size of *Eriogonum visheri*. Monitoring known occurrence sites at an appropriate and similar time over consecutive years and recording information on environmental conditions (including but not limited to temperature, precipitation and soil moisture) in conjunction with further inventory would substantially contribute to understanding the accuracy of Lenz's (1995) hypothesis. Understanding the relationships among abundance, seed set, and local climate conditions - especially precipitation and temperature – is critical to interpreting population trend observations.

Analysis of the genetic structure of the different *Eriogonum visheri* occurrences (see Demography section) would be very useful in determining which populations have the highest conservation value. There is no information on how much genetic variability is stored within a local population or how much occurs across the species. This type of study would clarify the genetic relationships between relatively small and isolated *E. visheri* occurrences and may contribute to understanding the dispersal characteristics of the taxon.

Understanding the reproductive mechanism in *Eriogonum visheri* would be valuable in developing management strategies for the species. If pollinators are crucial for sustainable populations, then how to maintain appropriate pollinator assemblage and abundance would need to be considered. Assessing how management practices, such as routine pesticide applications or livestock grazing, could be modified to ensure successful cross-pollination may be important to sustaining populations over the long-term.

The factors that limit population size and abundance and that contribute to variable occurrence sizes and patchy spatial distribution are not known and need to be determined. Obtaining an estimate of the dispersal capacity of *Eriogonum visheri* fruits may clarify why this species inhabits so little apparently suitable habitat.

The potential magnitude of the impact of non-native invasive species on *Eriogonum visheri* needs to be clarified. More information on how *E. visheri* responds to increased competition with non-native species and their impact on potential habitat is important because these species have an increasing presence in many parts of its range.

The prioritization of information needs depends upon management goals and may be influenced by changing circumstances. At the present time, the primary information gaps for *Eriogonum visheri* can be summarized as follows.

- ❖ Documented, formal monitoring studies of known occurrences to clarify the population dynamics and the taxon's vulnerability to disturbance

- ❖ Inventories in additional areas with appropriate geological formations to clarify the rarity and habitat requirements of the taxon

- ❖ Demographic and reproductive biology studies to clarify the vulnerability of individuals and populations to environmental, demographic, and genetic stochasticities as well as to specific management practices

- ❖ Analyses of the genetic structure of a range of *E. visheri* occurrences to clarify how much genetic variability is stored within local occurrences and how much occurs across the species; such studies may help to determine which occurrences have the highest conservation value

- ❖ Investigation of the causes of the patchy distribution of *E. visheri*, such as fruit dispersal characteristics
- ❖ Assessment of the potential impacts from invasive non-native plant species on *E. visheri* plants and their habitat.

DEFINITIONS

Achene – a small, usually single-seeded, dry fruit that remains closed at maturity; the simplest fruit.

Allelopathy – the release into the environment of a chemical substance that affects the germination or growth of another organism negatively (Allaby 1992).

Calyx – the outer series of the perianth, used especially when it differs in size shape or color from the inner petals (Harrington and Durrell 1986).

Capsule – a dry dehiscent fruit made up of more than one carpel (Harrington and Durrell 1986).

Clay – soil texture class; soil material that contains 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt (Soil Science Society of America 2006).

Conservation strategy – a conservation strategy is the Forest Service's documentation of the management actions necessary to conserve a species, species group, or ecosystem. A strategy uses the information provided in a conservation assessment to establish conservation objectives and develop the management actions needed to accomplish those objectives. Strategies are normally implemented through a forest plan addendum, amendment or revision, and/or interim for final Forest Service manual direction or an approved species plan (Zaber 1998).

Edaphic – (1) of or pertaining to the soil; (2) resulting from or influenced by factors inherent in the soil or other substrate, rather than by climatic factors (Soil Science Society of America 2006).

Endemic – of a species, found in nature only within a particular, usually small, geographic area.

Entomophilous – insect pollinated.

Geitonogamy – between-flower self-pollination.

Genetic drift – "is a process in which allele frequencies within a population change by chance alone as a result of sampling error from generation to generation. Genetic drift is a random process that can lead to large changes in populations over a short period of time. Genetic drift leads to fixation of alleles or genotypes in populations. Drift is probably common in populations that undergo regular cycles of extinction and recolonization" (McDonald 2004).

Granivory – feeding on seeds, grain.

Habitat fragmentation – continuous stretches of habitat become divided into separate fragments by land use practices such as agriculture, housing development, logging, and resource extraction, road construction; eventually, the separate fragments tend to become very small islands isolated from each other by areas that cannot support the original plant and animal communities.

Hermaphroditic – bisexual as related to a flower, having both stamens and carpels in the same flower.

Hillock – a small low hill, a mound (Bates and Jackson 1984).

Hymenoptera – an order of arthropods that includes bees, wasps, and ants.

Indeterminate – a plant that continues to produce flowers or fruit throughout the duration of the growing season.

Innate dormancy – a situation where a seed will not germinate even if conditions are favorable (Harper 1959); this is in contrast to "enforced dormancy" whereby the seed does not germinate because conditions are not favorable (Harper 1959).

Involucre – a whorl of distinct or united leaves or bracts subtending a flower or an inflorescence (Harrington and Durrell 1986).

Loam – soil texture class; soil material that contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand (Soil Science Society of America 2006).

Lignite – increased pressures and heat from overlying strata cause buried peat to dry and harden into lignite, which is a brownish-black coal with generally high moisture and ash content and lower heating value; lignite is an important form of energy for generating electricity (Mineral Information Institute available online at: www.mii.org).

Limonite – a generic term used for undifferentiated hydrated iron oxides - often hydrated goethite. Formula: $FeO(OH)\cdot nH_2O$ (Bates and Jackson 1984).

Metapopulation – a set of partially isolated populations belonging to the same species; the populations are able to exchange individuals and recolonize sites in which the species has recently become extinct (after Noss and Cooperrider 1994); a further explanation is that a metapopulation consists of a group of spatially separated populations of the same species, which interact at some level; the term metapopulation was coined by Levins (1969) to describe a model of population dynamics of insect pests in agricultural fields, but the idea has been broadly applied to species in naturally or artificially fragmented habitats.

Mitigate – to moderate something or make it less severe; the legal definition pertaining to law, as in mitigate damages - taking action to avoid or reduce damages is not inferred in this report.

Mutation – a change in the DNA at a particular locus in an organism; a weak force for changing allele frequencies, but a strong force for introducing new alleles (McDonald 2004); small populations have fewer different alleles because of genetic drift (see definition above) and because there are fewer individuals in which mutations can be generated (McDonald 2004).

Noxious weed – plant species of foreign origin that are new to or not widely prevalent in the United States, and can directly or indirectly injure useful plants, interests of agriculture, fish and wildlife resources or the public health of the United States (from United State Code as of 01/26/1998, Title 7-Agriculture, Chapter 61, Sec. 2802).

pH – the logarithm of the reciprocal of hydrogen-ion concentration in gram atoms per liter; it provides a measure on a scale from 0 to 14 of the acidity or alkalinity of a solution (where 7 is neutral and greater than 7 is basic and less than 7 is acidic).

Pollen discounting – reduction in pollen export to adjacent genetically dissimilar plants.

Potash – usually potassium chloride but can also refer to be potassium sulfate, potassium-magnesium sulfate, and potassium nitrate; used as a fertilizer, in medicine, in the chemical industry, and is used to produce decorative color effects on brass, bronze, and nickel; an essential mineral for vegetable and animal life (Mineral Information Institute available online at: www.mii.org).

Rank – according to NatureServe (2005):

Global rank G3 = Vulnerable. "Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals."

Subnational indicates jurisdictions at the state or provincial level (e.g. California, Ontario).

Subnational rank S1 = "Critically Imperiled—Critically imperiled in the subnation because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the subnation. Typically 5 or fewer occurrences or very few remaining individuals (<1,000)."

Subnational rank S2 = "Imperiled—Imperiled in the subnation because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000)."

Subnational rank S3 = "Vulnerable—Vulnerable in the subnation either because rare and uncommon, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals."

Ruderal – a plant that colonizes waste ground (Allaby 1992).

***r*-selected species –** a species that shows the following characteristics: short lifespan, early reproduction, low biomass, and the potential to produce large numbers of usually small offspring in a short period of time.

Sandy clay – soil texture class; soil material that contains 35 percent or more clay and 45 percent or more sand. (Soil Science Society of America 2006).

Scabrate – a term used to describe the ornamentation elements that are smaller than 1µm in all directions and have any shape on a pollen grain (Iversen and Troels-Smith 1950); in contrast, ornamentation elements larger than 1 µm are described according to their shape.

Scoria – a vesicular cindery crust (Bates and Jackson 1994); formed from the baking of clay strata during spontaneous combustion of nearby lignite seams in the Hell Creek formation (Woodard 2004).

Section – a subunit of a genus; a subunit of a genus; according to taxonomic principles, a genus can be divided into sections and sometimes further into sub-sections.

Seed discounting – the loss of outcrossed seeds due to selfing.

Stipule – an appendage at the base of the pertiole or leaf at each side of its insertion; often more or less united (Harrington and Durrell 1986).

Style – part of the female reproductive organs of the flower; the (usually) stalk-like part of a pistil connecting the ovary to the stigma (Harrington and Durrell 1986).

Succession – "The sequential change in vegetation either in response to an environmental change or induced by the intrinsic properties of the plants themselves. Classically, the term refers to the colonization of a new physical environment by a series of vegetation communities until the final equilibrium state, the climax, is achieved" (Allaby 1992).

Swale – a natural or human-made open depression or wide, shallow ditch; a swale does not usually direct water, but holds it and allows it to infiltrate the soil down-slope of it gradually; soil and water run-off are caught in the swale, which eventually becomes a fertile area.

Taxon – a group of organisms of any taxonomic rank; e.g., family, genus, or species (Allaby 1992).

Taxonomy – (from Greek "taxis" meaning "arrangement" or division and "nomos" meaning "law") the study of the classification of organisms according to their resemblances and differences (Abercrombie et al. 1973).

Tricolporate – pollen grains that have three pores and three furrows; the furrows being termed "colpi."

Trinucleate – pollen grains that have three nuclei.

References

Aasheim, R. 1980. Snowmobile impacts on the natural environment. *In*: R. Andrews and P. Nowak, editors. Off-road vehicle use: A management challenge. USDA Office of Environmental Quality, Washington, D.C.

Abercrombie, M., C.J. Hickman, and M.L. Johnson. 1973. A dictionary of biology. Sixth edition. Penguin Books Ltd, Middlesex, England, UK.

Abrahams, A.D. and A.J. Parsons. 1994. Geomorphology of desert environments. Chapman and Hall, New York, NY.

Adams, V., D. Marsh, and J. Knox. 2005. Importance of the seed bank for population viability and monitoring of an endangered wetland herb. Biological Conservation 124:425–436.

Alexander, H.M. and A.M. Schrag. 2003. Role of soil seed banks and newly dispersed seeds in population dynamics of the annual sunflower, *Helianthus annuus*. Journal of Ecology 91:987-998.

Allaby, M. 1992. The concise Oxford dictionary of botany. Oxford University Press, Oxford, England, UK.

Alley, R.B 2002. The two-mile time machine: Ice cores, abrupt climate change, and our future. Princeton University Press, Princeton, NJ.

Andrewartha, H.G. and L.C. Birch. 1984. The ecological web: more on the distribution and abundance of animals. University of Chicago Press, Chicago, IL.

Archibald, J.K., P.G. Wolf, V.J. Tepedino, and J. Bair 2001. Genetic relationships and population structure of the endangered Steamboat buckwheat, *Eriogonum ovalifolium* var. *williamsiae* (Polygonaceae). American Journal of Botany 88:608-615.

ATV Source 1999-2004. Available online at: http://www.atvsource.com/ [Accessed: December 2004].

Bailey, R.G. 1995. Description of the ecoregions of the United States. Originally published in 1978 and reprinted in 1980 by the USDA Forest Service, Washington, D.C., as Miscellaneous Publication No. 1391. Re-compiled in 1995 and available online at: http://el.erdc.usace.army.mil/emrrp/emris/emrishelp2/bailey_s_ecoregions_map.htm.

Barnett, J.K. and J.A. Crawford. 1994. Pre-laying nutrition of sage grouse hens in Oregon Journal of Range Management 47:114-118.

Barrett, S.C.H. and J.R. Kohn. 1991. Genetic and evolutionary consequences of small population size in plants: Implications for conservation. Pages 3-30 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Baskin, C.C. and J.M. Baskin. 2001. Seeds - ecology, biogeography, and evolution of dormancy and germination. Academic Press, New York, NY.

Baskin, J.M. and C.C. Baskin. 1989. Physiology of dormancy and germination in relation to seed bank ecology. Pages 53-66 *in* M.A. Leck, V.T. Parker, and R.L. Simpson, editors. Ecology of soil seed banks. Academic Press, New York, NY.

Bates, R.L. and J.A. Jackson. 1984. Dictionary of geological terms. Third edition. Anchor Books - Doubleday, New York, NY.

Beechie, B.W. 2004. Coal outcrop fire suppression in the Badlands. *In*: Proceedings of the 26th Annual NAAMLP Conference, Flagstaff, Arizona. Available in PDF online: http://www.psc.state.nd.us/jurisdiction/aml-pubs.html.

Belnap, J. 2002. Impacts of off-road vehicles on nitrogen cycles in biological soil crusts: resistance in different U.S. deserts. Journal of Arid Environments 52(2):155-165.

Belnap, J., J. Hilty Kaltenecker, R. Rosentreter, J. Williams, S. Leonard, and D. Eldridge. 2001. Biological soil crusts: Ecology and management. Technical Reference 1730-2. USDI Bureau of Land Management, Denver, CO.

Benedict, R.A., Freeman, P.W., Genoways, H.H., 1996. Prairie legacies - Mammals. *In*: F.B. Samson, and F.L. Knopf, editors. Prairie conservation. Island Press, Washington, D.C.

Berger, J. and C. Cunningham. 1995. Multiple bottlenecks, allopatric lineages and Badlands bison *Bos bison*: Consequences of lineage mixing. Biological Conservation 71(1):13-23.

Biota Information System of New Mexico BISON. 2004. Antelope America pronghorn, *Antilocapra americana americana* (NM,AZ). BISON database, The New Mexico Department of Game and Fish, and The Fish and Wildlife Information Exchange, Conservation Management Institute, VA Tech, Blacksburg, VA. Available online at: http://fwie.fw.vt.edu/states/nmex_main/species/050585.htm (Version January 2004).

Bond, W.J. 1995. Assessing the risk of plant extinction due to pollinator and disperser failure. *In*: J.H. Lawton and R.M. May, editors. Extinction rates. Oxford University Press, New York, NY.

Bosch, M. 2004. Forest Service Sensitive Species Summary. Designated Sensitive Species (that are not listed or proposed species under the ESA), as of 2 December 2004. USDA Forest Service, Watershed, Fish, Wildlife, Air, and Rare Plants Program, Washington, D.C. Available online at: http://www.fs.fed.us/biology/resources/pubs/tes/ss_sum_by_region_dec2004_fs.pdf.

Bourassa, M.A. 2001. Bighorn sheep restoration in Badlands National Park, South Dakota: lessons for cooperation. Proceedings of the 11th Conference on Research and Resource Management in Parks and on Public Lands, The 2001 GWS Biennial Conference. Report available online at: http://www.georgewright.org/20bouras.pdf.

Boutin, C., N. Elmegaard, and C. Kjær. 2004. Toxicity testing of fifteen non-crop plant species with six herbicides in a greenhouse experiment: Implications for risk assessment. Ecotoxicology 13(4):349-369.

Bryce, S., J.M. Omernik, D.E. Pater, M. Ulmer, J. Schaar, J. Freeouf, R. Johnson, P. Kuck, and S.H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. Northern Prairie Wildlife Research Center, Jamestown, ND. Available online at: http://www.npwrc.usgs.gov/resource/habitat/ndsdeco/ndsdeco.htm (Version 30 November 1998).

Byers, D. and D.M. Waller. 1999. Do plant populations purge their genetic load? Effects of population size and mating history on inbreeding depression. Annual Review of Ecology and Systematics 30:479-513.

Chamberlain, T.C. 1897. The method of multiple working hypotheses. Journal of Geology 5:837-848 (reprinted in Science 148:754-759).

Christy, J.R. 2000. Written Testimony of John R. Christy, University of Alabama in Huntsville to the Senate Committee on Commerce, Science and Transportation, 17 May 2000. Available online at: http://www.gcrio.org/OnLnDoc/pdf/pdf/christy000517.pdf [Accessed: January 2006].

Cosyns, E., S. Claerbout, I. Lamoot, and M. Hoffmann. 2005. Endozoochorous seed dispersal by cattle and horse in a spatially heterogeneous landscape. Plant Ecology 178:149–162.

D’Antonio, C.M. and P.M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23:63-87.

Diller, K.J. 2002. 2001 sensitive plant inventory, Dakota buckwheat (*Eriogonum visheri*). Unpublished document submitted to U.S. Forest Service Dakota Prairie Grasslands, Bismarck, ND.

Dingman, S. 2004. Technology for Resource Management - Using GIS to Focus Field Inventories of Rare and Endemic Plants at Badlands National Park, South Dakota. *In*: D. Harmon, B.M. Kilgore, and G.E. Vietzke, editors. Protecting our diverse heritage: The role of parks, protected areas, and cultural sites. Proceedings of the 2003 George Wright Society / National Park Service Joint Conference. The George Wright Society, Hancock, Michigan. Available in PDF online at: http://www.georgewright.org/0377dingman.pdf.

Durbin, T.D., M.R. Smith, R.D. Wilson, and S.H. Rhee. 2004. In-use activity measurements for off-road motorcycles and all-terrain vehicles. Transportation Research Part D - Transport and Environment 9(3):209-219.

Eckert, C.G. 2000. Contributions of autogamy and geitonogamy to self-fertilization in a mass-flowering, clonal plant. Ecology 81(2):532-542.

Elzinga, C.L., D.W. Salzer, and J.W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management Technical Reference 1730-1. USDI Bureau of Land Management, Denver, CO.

Elzinga, C., D. Salzer, J. Willoughby, and J. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Scientific Publishing, Boston, MA.

Environmental Media Services. 2001. Definitions for public land designations, Last update: April 27, 2001. Available online at: http://www.ems.org [Accessed: December 2003].

Evans, J.E. and L.C. Welzenbach. 2000. Lacustrine limestones and tufas in the Chadron formation (late Eocene), badlands of South Dakota. *In*: E.H. Gierlowski-Kordesh and K.R. Kelts, editors. Lake Basins through space and time. AAPG Studies in Geology 46:349-358.

Finn, S., S. Knick, and E.T. Rinkes. Impact of energy development on sagebrush ecosystems. Abstract. Annual Meeting of the Ecological Society of America in Portland, OR, August 1-6, 2004.

Fiori, S.M. and S.M. Zalba1 2003. Potential impacts of petroleum exploration and exploitation on biodiversity in a Patagonian Nature Reserve, Argentina. Journal Biodiversity and Conservation 12(6):1261-1270.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 8(3): 629-644.

Fox, G.A. 1989. Consequences of flowering time in a desert annual: adaptation and history. Ecology 70:1294-1306.

Fox, G.A. 1990. Drought and the evolution of flowering time in desert annuals. American Journal of Botany 77:1508-1518.

Fox, G.A. 2001. Failure time analysis: studying times-to-events and rates at which events occur. Pages 253-289 *in* S.M. Scheiner and J. Gurevitch, editors. Design and analysis of ecological experiments. Second editor. Oxford University Press, Oxford, UK. Preprint available online at: http://boojum.cas.usf.edu/downloads/FTA_preprint.pdf.

Fox, G.A. 2003. Assortative mating and plant phenology: evolutionary and practical consequences. Evolutionary Ecology Research 5:1-18.

Frankel O.H., A.H.D. Brown, and J.J. Burdon. 1995. The conservation of plant biodiversity. Cambridge University Press, New York, NY.

Frankham, R. 1999. Quantitative genetics in conservation biology. Genetic Research, Cambridge 74:237-244.

Franklin, I.R. 1980. Evolutionary change in small populations. Pages 135-150 *in* M.E. Soulé and B.A. Wilcox, editors. Conservation biology: An evolutionary-ecological perspective. Sinauer, Sunderland, MA.

Franklin, I.R. and R. Frankham. 1998. How large must populations be to retain evolutionary potential? Animal Conservation 1:69-71.

Freas, K.E. and P.R. Kemp. 1983. Some relationships between environmental reliability and seed dormancy in desert annual plants. Journal of Ecology 71:211-217.

Frye, C.I. 1969. Stratigraphy of the Hell Creek formation in North Dakota. North Dakota Geological Survey, Bulletin No. 54.

Geer, S.M. and V.J. Tepedino. 1993. Breeding systems of the rare heliotrope milkvetch (*Astragalus montii* Welsh: Fabaceae) and two common congeners. *In*: R. Sivinski and K. Lightfoot, editors. Proceedings of the southwestern rare and endangered plant conference. Based on the conference held March 30-April 2, 1992. Misc. Publication No. 2. New Mexico Forestry and Resources Conservation Division, Energy, Mineral and Natural Resources Department, Santa Fe, NM.

Gelbard, J.L. and S. Harrison. 2003. Roadless habitats as refuges for native grasslands: interactions with soil, aspect, and grazing. Ecological Applications 13(2):404-415.

Geography@Berkeley! 2005. Pollen key by family. Department of Geography, University of California, Berkeley, CA. Available online at: http://geography.berkeley.edu/ProjectsResources/PollenKey/byFamiliesAll-in-1.html#Polygonaceae.

Gitzendanner, M.A. and P.S. Soltis. 2000. Patterns of genetic variation in rare and widespread plant congeners. American Journal of Botany 87(6):783-792.

Goldsmith, F.B. 1991. Monitoring for conservation and ecology. Chapman and Hall, New York, NY.

Grant, G. and G. Gorman 2004. "Today the American Sand Association met with the Center for Biological Diversity (CBD) to discuss management options at The Imperial Sand Dunes Recreation Area (ISDRA)." Press Release – American Sand Association December 7, 2004, American Sand Association, La Verne, CA.

Grant, V. 1981. Plant speciation. Second edition. Columbia University Press, New York, NY.

Great Plains Flora Association. 1986. Flora of the Great Plains. University of Kansas Press, Lawrence, KS.

Grime, J.P., J.G. Hodgson, and R. Hunt. 1988. Comparative plant ecology, a functional approach to common British species. Unwin Hyman Ltd., London, UK.

Guala, G. 2006. National Plant Data Center. Personal communication.

Guralnik, D. 1982. Webster's New World Dictionary. Simon and Schuster. New York, NY.

Harper, J.L. 1959. The ecological significance of dormancy and its importance in weed control. Proceedings IVth International Congress of Crop Protection, Hamburg, 415-420.

Harrington, H.D. and L.W. Durrell. 1986. How to identify plants. Swallow Press, Athens, OH.

Hillborn, R. and M. Mangel. 1997. The ecological detective: confronting models with data. Princeton University Press, Princeton, NJ.

Hoganson, J.W. and J.H. Hartman. 2003. Paleontologists tour North Dakota's internationally significant fossil sites in association with the 2003 annual meeting of the Society of Vertebrate Paleontology. North Dakota Geological Survey Newsletter 30(2):1-7.

Inderjit. 2005. Allelopathy: challenges and achievements. General lecture 1:3. 17-23 July 2005. XVII International Botanical Congress, Vienna, Austria.

IUCN. 2004. The World Conservation Union, Species Survival Commission (SSC), IUCN Red List of Threatened Species^{TM}. Available online at: http://www.redlist.org/.

Iversen, J. and J. Troels-Smith, 1950. Pollenmorphologische Definitonen und Typen. Danmarks Geologiske Undersøgelse, series 4. 3(8):1-54.

Johns T.C., R.E. Carnell, J.F. Crossley, J.M.Gregory, J.F.B. Mitchell, C.A. Senior, S.F.B. Tett, and R.A. Wood. 1997. The Second Hadley Centre coupled ocean-atmosphere GCM: Model description, spinup and validation. Climate Dynamics 13:103-134.

Johnson, J.R. 1982. South Dakota grasslands, past and present. Bulletin 566. Agricultural Experiment Station, South Dakota State University, Brookings, SD.

Johnson, J.R. and G.E. Larson. 1999. Grassland plants of South Dakota and the northern Great Plains. South Dakota State University College of Agriculture and Biological Sciences, Brookings, SD.

Johnson, J.R. and J.T. Nichols. 1982. Plants of South Dakota grasslands. South Dakota State University, Brookings, SD.

Jones, J.K., Jr., D. Armstrong, R. Hoffman, and C. Jones, 1983. Mammals of the northern Great Plains. University of Nebraska Press, Lincoln, NE.

Karron J.D. 1991. Patterns of genetic variation and breeding systems in rare plant species. Pages 87-98 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Karron, J.D., Y.B. Linhart, C.A. Chaulk, and C.A. Robertson.1988. Genetic structure of geographically restricted and wide-spread species of *Astragalus* (Fabaceae). American Journal of Botany 75:1114-1119.

Kearns, C.A., D.W. Inouye, and N.M. Waser. 1998. Endangered mutualisms: the conservation of plant-pollinator interactions. Annual Review of Ecology and Systematics 29:83-112.

Keddy, P.A., A.J. Spavold, and C.J. Keddy. 1979. Snowmobile impact on old field and marsh vegetation in Nova Scotia, Canada: An experimental study. Environmental Management 88(10):409-415.

Keiding, N. 1975. Extinction and exponential growth in random environments. Theoretical Population Biology 8: 49-63.

Kemp, P.R. 1989. Seed banks and vegetation processes in deserts. Pages 257-282 *in* M.A. Leck, V.T Parker, and R.L. Simpson, editors. Ecology of soil seed banks. Academic Press, New York, NY.

Kostel, G. 2006. Graduate student, Department of Botany, University of Wyoming, Laramie, WY. Personal communication.

Küchler, A.W. 1966. Potential Natural Vegetation. Map, 1:7,500,000. National Atlas, USDI Geological Survey, Washington, D.C.

Ladyman, J.A.R. and E. Muldavin. 1996. Terrestrial Cryptogams as they relate to Pinyon Juniper Woodlands in the South Western United States. A Review. USDA Forest Service Rocky Mountain Experiment Station Publication RM-GTR-280. USDA Forest Service, Fort Collins, CO.

Lande, R. 1995. Mutation and conservation. Conservation Biology 9:782-791.

Lande, R. and G.F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87-123 *in* M. E. Soulé, editor. Viable populations for conservation. Cambridge University Press, Cambridge, UK.

Lanham, U. 1991. The bone hunters: The heroic age of paleontology in the American West. Dover Publications, Mineola, NY.

Laurenroth, W.K. and D.G. Milchunas. 1992. Short-grass steppe. *In*: R.T. Coupland, editor. Ecosystems of the world Vol. 8A: Natural grasslands, Introduction and western hemisphere. Elsevier, New York, NY.

Lenz, D. 1993. 1991-1992 Inventory of rare plant species in the Little Missouri National Grasslands. North Dakota Natural Heritage Program, Bismarck, ND.

Lenz, D. 1995. Target plant survey for *Eriogonum visheri* (Dakota buckwheat) in the Little Missouri National Grasslands and Mountrail, Grant, and Sioux counties North Dakota. North Dakota Natural Heritage Program, Bismarck, ND.

Lenz, D. 2003. 2003 Rare plant survey, Little Missouri National Grassland, Slope County, ND. Unpublished document prepared by North Dakota Natural Heritage Inventory, North Dakota Parks and Recreation Department for USDA Forest Service Dakota Prairie Grasslands, ND.

Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomology Society of America 71:237-240.

Li, F-R, T. Wang, A-S Zhang, Y-Y Zhao, L-F Kang, and W. Chen. 2005. Wind-dispersed seed deposition patterns and seedling recruitment of *Artemisia halodendron* in a moving sandy land. Annals of Botany 96(1):69-80.

Linabery, M. 1991. Sensitive plant sitings, Buffalo Gap National Grasslands, Wall Ranger District. Unpublished report. USDA Forest Service Buffalo Gap National Grasslands, SD.

Linabery, M. and J. Isaacs 1992. Sensitive plants habitat survey, White River land exchange. Unpublished report. USDA Forest Service Buffalo Gap National Grasslands, SD.

Locklear, J. Undated. Plant profile of *Eriogonum visheri*. Center for Plant Conservation (CPC) National Collection of Endangered Plants. Available online at: http://www.centerforplantconservation.org/ASP/CPC_ViewProfile.asp?CPCNum=1802.

Lym, R.G. 2004. North Dakota noxious and troublesome weeds. NDSU Extension Service publication W-1103 (Revised), April 2004. North Dakota State University, Fargo, ND. Available online at: http://www.ext.nodak.edu/

extpubs/plantsci/weeds/w1103w.htm.

MacArthur, R.H. and E.D. Wilson. 1967. The theory of island biogeography. Princeton University Press, Princeton, NJ.

Mack, R.N. and J.N. Thompson. 1982. Evolution in steppe with few large hooved mammals. The American Naturalist 119(6):757-773.

McDonald, B.A. 2004. Population genetics of plant pathogens. *In*: The plant health instructor. DOI: 10.1094/PHI-A-2004-0524-01. American Phytopathological Society, St. Paul, MN. Available online at: http://www.apsnet.org/education/AdvancedPlantPath/Topics/PopGenetics/top.htm.

McGillivray, G. 2005 South Dakota horizontal drilling and oil and gas activity update. South Dakota Department of Environment and Natural Resources (DENR), Minerals and Mining Program - Oil and Gas Section, rapid City, SD. Available online at: http://www.state.sd.us/denr/DES/Mining/Oil&Gas/O&Ghome.htm.

McNab, W.H. and P.E. Avers 1994. Ecological subregions of the United States: Section descriptions. Administrative Publication WO-WSA-5. USDA Forest Service, Washington, D.C.

Mehroff, L.A. 1989. The dynamics of declining populations of an endangered orchid, *Isotria medeoloides*. Ecological Publications of Ecological Society of America. 70:783-786.

Menges, E.S. 1991. The application of minimum viable population theory to plants. Pages 45-61 *in* D.A. Falk and K.E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Menges, E.S. and P. Quintana-Ascencio. 2002. *Eriogonum longifolium* Species Account. 12 July Archbold Biological Station, Lake Placid, FL. Available online at: http://www.archbold-station.org/ABS/plantspp/erilonsppacc.htm [Accessed: April 2006].

Meyer, S.E. and A. Paulsen. 2000. Chilling requirements for seed germination of 10 Utah species of perennial Wild Buckwheat. Native Plants Journal 1:18-24.

Miller, W.H. and M. Drake. 2003. Nutritional concerns of pronghorn antelope on Anderson Mesa and Garland Prairie, Arizona. Final Report Submitted to Arizona Game and Fish Department, Phoenix, AZ. Available online at: http://azantelope.org/Facts___Research/facts___research.html.

Misak, R.F., J.M. Al Awadhi, S.A. Omar, and S.A. Shahid. 2002. Soil degradation in Kabd area, southwestern Kuwait city. Land Degradation and Development. 13(5):403-415.

Montana Natural Heritage Program. 1997-2005. Montana rare plant field guide. Montana Natural Heritage Program, Helena, MT. Available online at http://nhp.nris.state.mt.us/plants/index.html [Accessed: May 2005].

Montana Natural Heritage Program. 2005. Data compilation for *JnJ Associates* LLC, completed 2005. Unpublished report. Montana Natural Heritage Program, Helena, MT.

Moseley, R.K. 1989. Report on the conservation status of Phacelia inconspicua in Idaho. Unpublished report to the Idaho Department of Fish and Game, Boise, ID.

National Oceanic and Atmospheric Administration. 2004. CoRIS - NOAA's Coral Reef Information System (http://coris.noaa.gov/welcome.html). Glossary section. Available online at: http://www6.nos.noaa.gov/coris/glossary.lasso?letter=p.

NatureServe. 2004. Natural heritage methodology: A habitat-based strategy for delimiting plant element occurrences: Guidance from the 2004 Working Group NatureServe, Arlington, VA. Available online at: http://www.natureserve.org/library/deliminting_plant_eos_Oct_2004.pdf.

NatureServe. 2005. NatureServe Explorer: An online encyclopedia of life [web application]. Version 4.4. NatureServe, Arlington, VA. Available online at: http://www.natureserve.org/explorer [Accessed: May 2005].

Neel, M.C., J. Ross-Ibarra, and N.C. Ellstrand. 2001. Implications of mating patterns for conservation of the endangered plant *Eriogonum ovalifolium* var. *vineum* (Polygonaceae). American Journal of Botany 88 (7):1214-1222.

Nelson, A. 1913. Contributions from the Rocky Mountain Herbarium. XIII. Botanical Gazette. 56:63-71.

New York Botanical Garden Herbarium. Botanical Science Division, Bronx, NY. Available online at: http://www.nybg.org [Accessed: February 2004].

New Zealand Climate Change Office. 2006. Global climate change. New Zealand Ministry for the Environment. Available online at: http://www.climatechange.govt.nz [Accessed: January 2006].

North Dakota Natural Heritage Inventory. 2003. 2003 Rare plant survey Little Missouri National Grassland Slope County, ND. North Dakota Parks and Recreation Department, ND. Unpublished report for the USDA Forest Service Dakota Prairie Grasslands, ND.

North Dakota Natural Heritage Inventory. 2005. Data compilation for *JnJ Associates* LLC, completed 2005. Unpublished report. North Dakota Natural Heritage Inventory, North Dakota Parks and Recreation Department, ND.

North Dakota Petroleum Council. 2004. News: NDPC's 2005 Facts and Figures Brochure: North Dakota 's oil patch stats for 2004 - August 05 2004. North Dakota Petroleum Council, Bismarck, ND. Available online at: http://www.ndoil.org/index.html.

Noss, R.F. and A.Y. Cooperrider. 1994. Saving natures' legacy: Protecting and restoring biodiversity. Defenders of Wildlife. Island Press, Washington, D.C. and Covelo, CA.

Ocumpaugh, W.R., S. Archer, and J.W. Stuth. 1996. Switchgrass recruitment from broadcast seed vs. seed fed to cattle. Journal of Range Management 49:368-371.

Ode, D. 1987. The status of Dakota Wild Buckwheat, (*Eriogonum visheri* A. Nels.) in South Dakota: report to the U.S. Fish and Wildlife Service Endangered Species Office, Denver, CO. South Dakota Game, Fish, and Parks Department, Pierre, SD.

Ode, D. 1988. Four endemic plants of the northern Great Plains. Proceedings of the North Dakota Academy of Science 42:7.

OffRoadDirectory.net. 2004.The online directory to the world of off-roading. Available online at: http://offroaddirectory.net/atv.htm [Accessed: December 2004].

Osborne, J.L., S.J. Clark, R. Morris, I. Williams, R. Riley, A. Smith, D. Reynolds, and A. Edwards. 1999. A landscape-scale study of bumble bee foraging range and constancy, using harmonic radar. Journal of Applied Ecology 36: 519-533.

Ostlie, W.R., R.E. Schneider, J.M. Aldrich, T.M. Faust, R.L.B. McKim, and S.J. Chaplin. 1997. The status of biodiversity in the Great Plains. The Nature Conservancy, Arlington, VA.

Over, W.H. 1932. Flora of South Dakota. The University of South Dakota, Vermillion, SD.

Peden, D.G., G.M. Ven Dyne, R.W. Rice, and R.M. Henlen. 1974. The trophic ecology of *Bison bison* L. on shortgrass plains. Journal of Applied Ecology 11:489-498.

Pembina Institute. 2006. Wildlife and Oil and Gas. Resource development in the north – fact sheet. Available online at: http://www.pembina.org/pdf/publications/BC_oilgas10.pdf.

Perez, C.J., S.S. Waller, L.E. Moser, J.L. Stubbendieck, and A.A.Steuter 1998. Seedbank characteristics of a Nebraska sandhills prairie. Journal of Range Management 51:55-62.

Perisho, E.C. and S.S. Visher. 1912. The geography, geology, and biology of south-central South Dakota. State Geological and Biological Survey. Bulletin 5.

Peterson, M. 1997. Host plant phenology and butterfly dispersal: Causes and consequences of uphill movement. Ecology 78:167-180.

Peterson, M.A. 1995. Phenological isolation, gene flow and differential differences among low- and high-elevation populations of *Euphilotes enotes* (Lepidoptera: Lycaenidae). Evolution 49(3):446-455.

Pew Center. 2005. Global climate change, Pew Center, Arlington, VA. Available online at: http://www.pewclimate.org

[Accessed: January 2005].

Pimm, S.L., H.L. Jones, and J. Diamond. 1988. On the risk of extinction. American Naturalist 132:757-785.

Pivorunas, D. 2005. Forest Service Sensitive Species Summary Designated Sensitive Species (that are not listed or proposed species under the ESA), as of 31 October 2005. USDA Forest Service, Watershed, Fish, Wildlife, Air, and Rare Plants Program, Washington, D.C. Available online at: http://www.fs.fed.us/biology/resources/pubs/.

Platt, J.R. 1964. Strong inference. Science 146:347-353.

Plumb, G.E. and J.L. Dodd. 1993. Foraging ecology of bison and cattle on northern mixed prairie: Implications for Natural Areas management. Ecological Applications 3:631-643.

Pollard, J.H. 1966. On the use of the direct matrix product in analyzing certain stochastic population models. Biometrika 53:397-415.

Pratt, G.F. 1994. Evolution of *Euphilotes* (Lepidoptera: Lycaenidae) by seasonal and host shifts. Biological Journal of the Linnean Society 51:387-416.

Quammen, D. 1996. The song of the dodo: Island biogeography in an age of extinction. Scribner, New York, NY.

Ramsey, G., C.E. Thompson, S. Neilson, and G.R. Mackay. 1999. Honeybees as vectors of GM oilseed rape pollen. *In*: P.J.W. Lutman, editor. Gene flow and agriculture: Relevance for transgenic crops. BCPC Symposium Proceedings no. 72.

Reveal, J.L. 1969. A revision of the genus. *Eriogonum* (Polygonaceae). Unpublished. Ph.D. dissertation, Brigham Young University, Provo, UT.

Reveal, J.L. 1976. *Eriogonum* (Polygonaceae) of Arizona and New Mexico. Phytologia 34, 5:409-484.

Reveal, J.L. 1978 Distribution and phylogeny of Eriogonoideae (Polygonaceae). Great Basin Naturalist Memoirs Number 2, Intermountain Biogeography: A Symposium: 169-190.

Reveal, J.L. 2003. Eriogonoideae (Polygonaceae) of North America north of Mexico, Key to the Genera. Revised 8 Dec 2003. University of Maryland, Maryland. Available online at: http://www.life.umd.edu/emeritus/reveal/pbio/eriog/key.html.

Reveal, J.L. 2005a. University of Maryland; Honorary Curator with the New York Botanical Garden; Research Associate with the Academy of Natural Sciences and the Missouri Botanical Garden. Personal communications.

Reveal, J.L. 2005b. *Eriogonum*, Eriogonoidae, Polygonaceae. Flora of North America 5:218- 430.

Ridley, H.N. 1930. The dispersal of plants throughout the world. L. Reeve and Co., Ashford, UK.

Royer, R.A. 1995-1996. A comprehensive annotated list of the butterflies (Lepidoptera: Rhopalocera) occurring in the Little Missouri National Grassland. Billings, Golden Valley, McKenzie and Slope Counties, North Dakota. USGS Northern Prairie Wildlife Research Center. Available online at: http://www.npwrc.usgs.gov/resource/insects/bflysurv/littmo/littmo.htm.

Ryerson, D.K., D.A. Schlough, C.L. Foreman, G.H. Tenpas, and J.W. Pendleton. 1977. Effects of snowmobile traffic on several forage species and winter wheat. Agronomy Journal 69(5):769-772.

Sargent, D. 2005. USDA Forest Service, Wall Ranger District, Buffalo Gap National Grasslands, SD. Personal communication.

Sargent, D. 2006. USDA Forest Service, Wall Ranger District, Buffalo Gap National Grasslands, SD. Personal communication.

Sarukhan, J., M. Martinez-Ramos, and D. Pinero. 1984. The analysis of demographic variability at the individual level and its population consequences. Pages 83-106 *in* R. Dirzo and J. Sarukan, editors. Perspectives on plant population ecology. Sinauer, Sunderland, MA.

Schmoller, D.A. 1993. Status survey for *Eriogonum visheri*. USDA Forest Service - Region 2, Nebraska National Forest, Wall, SD.

~~Schmoller, D.A. 1995. Biological Evaluation of *Eriogonum visheri* populations for 1995 Grazing Permit Reissuance:~~

USDA Forest Service - Region 1, Custer National Forest. Ashland, MT.

Schmoller, D.A. 1996. Element stewardship abstract for *Eriogonum visheri*. The Nature Conservancy, Twin Cities, MN.

Scott, J.A. 1997. The butterflies of North America: a natural history and field guide. Stanford University Press, Stanford, CA.

Shea, K. and D. Kelly. 1998. Estimating biocontrol agent impact with matrix models: *Carduus nutans* in New Zealand. Ecological Applications 8(3):824-832.

Sheley, R.L. and J.K. Petroff. 1999. Biology and management of noxious rangeland weeds. Oregon State University Press, Corvallis, OR.

Sidle, J.G. 1998. Matrix of "listed" species in the Great Plains of North America and their occurrence on national grasslands. Great Plains National Grasslands USDA Forest Service, Chadron, Nebraska. Document accessible on the Internet. Internet site: http://www.fs.fed.us/r2/nebraska/gpng/matrix/matrix.html [Accessed: December 2004].

Silvertown, J.W. 1987. Introduction to plant population ecology. Second edition. Longman Scientific and Technical, Harlow, UK.

Soil Science Society of America. 2006. Internet glossary of soil science terms. Available online at: http://www.soils.org/sssagloss/index.php. Also available as a hardcopy edition published 2001, Soil Science Society of America, Madison, WI.

Soulé, M.E. 1987. Viable populations for conservation. Cambridge University Press, Cambridge, MA.

South Dakota Department of Agriculture. 2005. Local noxious weed list. Plant Protection Program, South Dakota Department of Agriculture. Available online at: http://www.state.sd.us/doa/das/hp-w&p.htm [last Modified: 06/23/2005 14:55:45].

South Dakota Natural Heritage Program. 2005. Data compilation for *JnJ Associates* LLC, completed 2005. Unpublished report. South Dakota Natural Heritage Program, South Dakota Department of Game Fish and Parks, Rapid City, SD.

Stebbins, G.L. 1942. The genetic approach to problems of rare and endemic species. Madroño 6:241–272.

Stebbins, G.L. 1980 Rarity of plant species: a synthetic viewpoint. Rhodora 82:77–86.

Stevens, O.A. 1963. Handbook of North Dakota plants. Third printing. North Dakota Institute for Regional Studies, Fargo, ND.

Stokes, S.G. 1936. The genus *Eriogonum*, a preliminary study based on geographic distribution. J.H. Neblett Pressroom, San Francisco, CA.

Stubbendieck, J., G.Y. Friisoe, and M.R. Bolick. 1994. Weeds of Nebraska and the Great Plains. Nebraska Department of Agriculture, Bureau of Plant Industry. Lincoln, NE.

Trimble, D.E. 1980. The geologic story of the Great Plains. Geological Survey Bulletin #1493. United States Government Printing Office, Washington D.C.

U.S. Census Bureau. Source U.S. Census Bureau: Data derived from Population Estimates, 2000 and Census of Population and Housing, 1990. Available online at: http://www.census.gov/.

U.S. Environmental Protection Agency. 1998a. Climate change and South Dakota. EPA 236-F-98-007x. Office of Policy, Planning, and Evaluation - Climate and Policy Assessment Division, Washington D.C.

U.S. Environmental Protection Agency. 1998b. Climate change and North Dakota. EPA 236-F-98-007d. September 1998. Office of Policy, Planning, and Evaluation - Climate and Policy Assessment Division, Washington, D.C.

U.S. Global Change Research Program. 2006. U.S. Climate Change Science Program/U.S. Global Change Research Program, Washington, D.C. Available online at: www.usgcrp.gov [Accessed: January 2006].

United States House of Representatives. 2005. The Committee on Energy and Commerce, Subcommittee on Energy and Air Quality Washington, D.C. Available online at: http://energycommerce.house.gov/108/News/.

United States Senate. 2005. Bipartisan Bill H.R. 6, June 28, 2005. Committee on Energy and Natural Resources, Washington, D.C. Available online at: http://energy.senate.gov/public/.

USDA Forest Service. 2001a. The Northern Great Plains Management Plan - the Dakota Prairie Grasslands, and the Medicine Bow-Routt and Nebraska National Forests. USDA Forest Service Northern and Rocky Mountain Regions. Available online at: http://www.fs.fed.us/ngp/plan/feis_chpts_appx.htm [Accessed: June 2005].

USDA Forest Service. 2001b. Travel notice, effective July 1 2001. Grand River and Cedar River National Grasslands Map. America's Great Outdoors – North Dakota and South Dakota – 1995. Issued by USDA Forest Service, Northern Region. Also available online at: http://www.fs.fed.us/r1/dakotaprairie/non_motorized.html.

USDA Forest Service. 2002. Record of Decision - Revised Land and Resource Management Plan for the Nebraska and Samuel R. McKelvie National Forests, Oglala, Buffalo Gap, and Fort Pierre National Grasslands. Available online at: http://www.fs.fed.us/ngp/plan/NNF_ROD_7_16_final.pdf [Accessed: July 2005].

USDA Forest Service. 2003a. Region 2. Threatened, endangered and sensitive plants and animals. Supplement No.: 2600-2003-1. Unpublished document. USDA Forest Service, Denver, CO.

USDA Forest Service. 2003b. Dakota, Minnesota, and Eastern Railroad Powder River Expansion Project (located on the Thunder Basin, and Buffalo Gap Grasslands). Records of Decision 2003; Appendix F – map of proposed rail road over Buffalo Gap National Grassland; Appendix H – Biological Assessment. Available online at: http://www.fs.fed.us/r2/mbr/projects/specper/index.shtml [Accessed: January 2006].

USDA Forest Service. 2004. Nebraska and Samuel R. McKelvie National Forests, Buffalo Gap, Fort Pierre, and Oglala National Grasslands - Local News Releases 2004. Available online at: http://www.fs.fed.us/r2/nebraska/news/2004/ [Accessed: July 2005].

USDA Forest Service. 2005a. Forest Service sensitive species that are not listed or proposed species under the ESA, 31 October 2005. Available online at: http://www.fs.fed.us/biology/tes/ [Accessed: November 2005].

USDA Forest Service. 2005b. Dakota Prairie Grasslands Noxious Weed Management Strategy EIS Dakota Prairie Grasslands; North Dakota and South Dakota. Federal Register 70 (113):34442-34444.

USDA Natural Resources Conservation Service. 2004. The PLANTS Database, Version 3.5. National Plant Data Center, Baton Rouge, LA 70874-4490. Available online at: http://plants.usda.gov.

USDA Southern Plains Agricultural Research Center. 2001. Atlas of scanning electron micrographs (SEM) of pollen grains. Available online at: http://pollen.usda.gov/AtlasSEMPlates/plates%2011_20/Plate%2020.htm (last edited Tuesday, June 19, 2001).

USDI Bureau of Land Management and U.S. Geological Survey, the Department of Agriculture's U.S. Forest Service, and the Department of Energy's Office of Fossil Fuels and Energy Information Administration. 2002. Energy Policy and Conservation Act Inventory fact sheet, information current as of 9:30 am January 15, 2002.

USDI Fish and Wildlife Service 1993. Endangered and threatened wildlife and plants. Federal Register. September 30. 50CFR, Part 17, Vol. 58, No. 188:51144-51190.

USDI Fish and Wildlife Service. 1995. North Dakota's federally listed endangered, threatened, and candidate species 1995. USDI Fish and Wildlife Service, Bismarck, ND published by Northern Prairie Wildlife Research Center, Jamestown, ND. Available online at: http://www.npwrc.usgs.gov/resource/distr/others/nddanger/nddanger.htm [Accessed: April 2005] (Version 16-Jul-97).

USDI Fish and Wildlife Service. 2000. Ecosystem plan for Upper Missouri, Yellowstone, and Upper Columbia River. November 2000. Available online at: http://moyoco.fws.gov/moyoco_plan.pdf. Revisions in 2003 available online at: http://moyoco.fws.gov/index.html.

USDI National Park Service. 2003. Badlands National Park, Integrated Weed Management Plan and Environmental

Assessment, March 2003. Badlands National Park, Pennington, Jackson, and Shannon Counties, SD. Available in PDF online at: http://planning.nps.gov/document/badl_draft_weed_plan.pdf.

USDI National Park Service. 2004. Badlands National Park Fire Management Plan – 2004. Badlands National Park, Pennington, Jackson, and Shannon Counties, SD. Available in PDF online at http://www.nps.gov/archive/badl/press/pr3-30-04.html.

USGS Biological Resources Division. 2004. Global Climate Change and Range Shifts of Prairie Nesting Birds: Will the Habitat Be There? USGS Global Change Research in Biology; August 1999 - September 2003. Primary Contact: Douglas H. Johnson, USGS Northern Prairie Wildlife Research Center. Available online at: http://www.nrel.colostate.edu/projects/brd_global_change/proj_55_prairie_birds.html [Accessed: June 2004].

USGS National Park Service Vegetation Mapping Program 1997. Badlands National Park Physical Descriptive Data for Plots. Available online at: http://biology.usgs.gov/npsveg/badl/fielddata.html.

USGS Northern Prairie Wildlife Research Center. Undated. Account of Dakota Wild Buckwheat (*Eriogonum visheri*). Available online at: http://www.npwrc.usgs.gov/resource/distr/others/nddanger/species/eriovish.htm.

Vaculik, L.S. 2001. Dakota Prairie National Grassland, Little Missouri and Cedar River National Grasslands, reasonably foreseeable development scenario for oil and gas. USDA Forest Service-Region 1. Available in PDF online at: http://www.fs.fed.us/ngp/final/pdf_feis_append/rfd_little_missouri.pdf.

Van Bruggen, T. 1976. The vascular plants of South Dakota. The Iowa State University Press, Ames, IA.

Van Bruggen, T. 1985. The vascular plants of South Dakota. Second edition. The Iowa State University Press, Ames, IA.

Vanderhorst, J., S.V. Cooper, and B.L. Heidel. 1998. Botanical and vegetation survey of Carter County, Montana. Unpublished report to Bureau of Land Management. Montana Natural Heritage Program, Helena, MT.

Vanderpool, S.S. 1993. Distribution and occurrence of *Eriogonum visheri* A. Nels. on the Medora and McKenzie Districts, Little Missouri National Grasslands, in North Dakota. Unpublished report to the North Dakota Natural Heritage Program. Institute for Ecological Studies, University of North Dakota, Bismarck, ND.

Visher, S.S. 1912. The biology of south-central South Dakota. State Geological and Biological Survey. Bulletin 5: 66-130.

Visher, S.S. 1914. A preliminary report on the biology of Harding County, Northwestern South Dakota. State Geological and Biological Survey. Bulletin 6:1-116.

Washington, J.P. 2005. Botanist. USDA Forest Service Little Missouri National Grasslands, Medora Ranger District, Dickinson, ND. Personal communication.

Wender, N.J., C.R. Polisetty, and K. Donohue. 2005. Density-dependent processes influencing the evolutionary dynamics of dispersal: a functional analysis of seed dispersal in *Arabidopsis thaliana* (Brassicaceae). American Journal of Botany 92:960-971.

Will-Wolf, S. 1998. Lichens of Badlands National Park, South Dakota. *In*: M.G. Glenn, R.C. Harris, R. Dirig, and M.S. Cole, editors. *Lichenographia thompsoniana*: North American Lichenology, in honor of John W. Thomson. Mycotaxon Ltd, Ithaca, NY.

Woodard, H.J. 2004. Geology of central-western South Dakota. South Dakota State University, Brookings, South Dakota. Available online at: http://plantsci.sdstate.edu/woodardh/Geology/Central_Western/index_geology_centralwestern.htm (Updated March 23, 2004).

Zaber, D.J. 1998. Southern lessons: Saving species through the National Forest Management Act. Section 2 - Conserving Native Biodiversity in the National Forests. Available online at: http://www.defenders.org/pubs/sfor04.html.

List of Errata

1/10/07 Table 1 (pages 23 and 24): Replaced the following under "Habitat" column

SD - No. 75: "On a badlands clay shelf sloping into a deep-cut drainage, soils are heavy white clay. Elevation approximately 6,687 feet" with "On a badlands clay shelf sloping into a deep-cut drainage, soils are heavy white clay. Elevation approximately 2,038 feet".

SD - No. 76: "Flat to rolling grass uplands draining into clay basin floodplains; soils are sand and silt on uplands to heavy clay in basin bottoms. Elevation approximately 7,146 feet" with "Flat to rolling grass uplands draining into clay basin floodplains; soils are sand and silt on uplands to heavy clay in basin bottoms. Elevation approximately 2,178 feet".

SD - No. 77: "Flat to rolling grass uplands draining into clay basin floodplains; soils are sand and silt on uplands to heavy clay in basin bottoms. Elevation approximately 7,182 feet" with "Flat to rolling grass uplands draining into clay basin floodplains; soils are silt and sand on uplands and heavy clay in basin bottoms. Elevation approximately 2,189 feet".